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Nos. 82-524, 82-545, and 82-551

IN THE

Supreme Court of the United States

OCTOBER TERM, 1982

BALTIMORE GAS AND ELECTRIC COMPANY, *et al.*,
Petitioners

v.

NATURAL RESOURCES DEFENSE COUNCIL, INC.,
Respondent

UNITED STATES NUCLEAR REGULATORY COMMISSION, *et al.*,
Petitioners

v.

NATURAL RESOURCES DEFENSE COUNCIL, INC., *et al.*,
Respondents

COMMONWEALTH EDISON COMPANY, *et al.*,
Petitioners

v.

NATURAL RESOURCES DEFENSE COUNCIL, INC., *et al.*,
Respondents

On Writs of Certiorari to the United States Court of Appeals for the District of Columbia Circuit

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JOINT APPENDIX

(Counsel of Record Appear on Inner Cover)

PETITIONS FOR CERTIORARI FILED SEPTEMBER 24, 27, AND 28, 1982
CERTIORARI GRANTED NOVEMBER 29, 1982

TIMOTHY B. ATKESON
STEPTOE & JOHNSON
CHARTERED
1250 Connecticut Ave., N.W.
Washington, D.C. 20036
(202) 862-2084

Counsel of Record for Respondent Natural Resources Defense Council, Inc.

EZRA I. BIALIK
Office of the Attorney General of the State of New York
Two World Trade Center
New York, New York 10047
(212) 488-7565

Counsel of Record for Respondent State of New York

HENRY V. NICKEL
HUNTON & WILLIAMS
P.O. Box 1?230
1919 Pennsylvania Ave., N.W.
Washington, D.C. 20036
(202) 223-8650

Counsel of Record for Petitioners Baltimore Gas and Electric Company, et al.

REX E. LEE
Solicitor General
Department of Justice
Washington, D.C. 20530
(202) 633-2217

Counsel of Record for Petitioners Nuclear Regulatory Commission and United States of America

MARTIN G. MALSCH
Acting General Counsel
Nuclear Regulatory Commission
Washington, D.C. 20555
(202) 634-1465

JAMES P. MCGRANERY, JR.
LEBOEUF, LAMB, LEIBY & MACRAE
Suite 1100
1333 New Hampshire Ave., N.W.
Washington, D.C. 20036
(202) 457-7500

Counsel of Record for Petitioners Commonwealth Edison Company, et al.

SAM KAZMAN
PACIFIC LEGAL FOUNDATION
Suite 550
1990 M Street, N.W.
Washington, D.C. 20036
(202) 466-2686

Counsel of Record for Respondent Pacific Legal Foundation

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* In recognition of the value that these voluminous documents may have to the Court in its consideration of the consolidated cases and the absence of their general availability, Petitioners have lodged 15 copies of each with the Clerk for the convenience of the Court.

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[DOCKET ENTRIES IN THE COURT BELOW
IN
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GENERAL DOCKET

UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

DATE	FILINGS—PROCEEDINGS	Filed
(L) 6- 7-74	4—Petitioner's petition for review of an order of the AEC (m-7)	
(L) 6- 7-74	Certified copy of a petition for review of an order of the AEC was mailed to AEC and the U.S. Attorney General	
(G) 6-27-74	4—Petitioners' motion to consolidate with No. 74-1385 (m-26)	
(L) 7- 5-74	4—Respondents' opposition to motion to consolidate (m-5)	
(B) 7- 8-74	4—Motion of Baltimore Gas and Electric Company, et al., for leave to intervene (m-8)	
(B) 7- 8-74	4—Opposition of intervenor, Vermont Yankee Nuclear Power Corp., to motion to consolidate (m-8) 74-1385	
(L) 7-15-74	4—Supplemental Certificate of Service for filing the petition for review	
(M) 7-17-74	Clerk's order granting motions by Baltimore Gas and Electric Co., Boston Edison Co., Consumers Power Co., Long Island Lighting Co., New England Electric System, Northeast Utilities Co., Pacific Gas & Electric Co., Philadelphia Electric Co., Public Service Electric & Gas Co., San Diego Gas & Electric Co., Southern California Edison Co., Virginia Electric & Power Co., and Yankee Atomic Electric Co., for leave to intervene; counsel for the intervenors are encouraged to file joint briefs whenever practicable and may participate in oral argument only to the extent allowable under Rule 12 of the General Rules of this Court	

DATE	FILINGS—PROCEEDINGS	Filed
(L) 7-17-74	Certified Index to the Record (n-4) (m-17)	
(L) 7-26-74	4—Petitioners' motion for leave to proceed under Rule 30(c) deferred appendix (m-26)	
(M) 8- 2-74	Clerk's order that the parties are granted leave to proceed under Rule 30(c) of the FRAP; in lieu of submitting one copy of the typewritten or page proof brief provided under Rule 30(c) of the FRAP, counsel for the parties shall submit seven copies thereof for filing	
(L) 8- 5-74	4—Intervenor's (Balt. Gas & Electric Co., et al) motion to substitute (4) electric utility companies in place and stead of Intervenor Northeast Utilities Company; (Connecticut Light & Power Company; Hartford Electric Light Company; Western Massachusetts Electric Company; Northeast Nuclear Energy Co;) and to substitute New England Power Company in place of New England Electric System (m-5)	
(I) 8-16-74	4—Petitioners' motion to extend time to file brief to 30 days from the date of order granting or denying petitioners' motion to consolidate (m-16) TMC	
(O) 8-22-74	4—Intervenor's (Baltimore Gas & Electric Company, et al.) motion for leave to file opposition to motion to consolidate nos. 74-1385 and 74-1586 (m-23) TMC See 74-1385	
(M) 8-29-74	Order per Wright ACJ, granting intervenors' (Baltimore Gas & Electric Co., et al) motion to substitute the following four electric utility companies instead of intervenor, Northeast Utilities Co.: *The Connecticut Light & Power Company*; *The Hartford Electric Light Company*; *Western Massachusetts Electric Company*; and *Northeast Nuclear Energy Company*; and intervenors' also move to substitute *New England Power Company* in place of New England Electric System	
(M)10- 3-74	Order per CJ Bazelon denying motions to consolidate; the time for filing petitioners' brief in the appeal is extended to November 2nd; sua sponte, that the Clerk is directed to schedule this case for oral argument on the same day and before the same panel of this Court as appeal no. 74-1385	

DATE	FILINGS—PROCEEDINGS	Filed
(L)11- 4-74	7—Petitioners' Brief (m-4)	
(G)11-12-74	4—Petitioners' motion to correct errors in brief (m-12) 11-25	
(M)11-18-74	Clerk's order granting petitioners' motion to correct errors in brief	
(M)11-27-74	4—Respondents' motion to extend time to file brief to February 7th (m-26)	
(M)11-29-74	4—Intervenors' Baltimore Gas and Electric Co., et al motion to extend time to file brief to February 7th (m-27)	
(M)12- 4-74	Clerk's order granting respondent's motion to extend time to file brief to Feb. 7th	
(M)12- 5-74	Clerk's order granting intervenors' Baltimore Gas and Electric Co., et al to extend time to file brief to February 7th	
(B) 12- 9-74	4—Motion of Commonwealth Edison Company, et al., for leave to file brief amici curiae (m-9) 12-22	
(M)12-27-74	Order per CJ Bazelon granting motion of Commonwealth Edison Co., et al for leave to file brief amici curiae	
(M)12-27-74	25—Brief for Amici Curiae Commonwealth Edison Co., et al (m-9)	
(I) 1-28-75	4—Respondents' motion to extend time to file brief to March 24th (m-28)	
(G) 2- 6-75	4—Petitioners' opposition to motion to extend time to file brief (m-6)	
(L) 2-10-75	7—Intervenors' Brief (m-7)	
(R) 2-14-75	Order per CJ Bazelon that the time for filing respondents' brief is extended to March 11, 1975; the time for filing petitioners' reply brief, if any, to respondents and intervenors' briefs is extended for a period of 14 days from the date respondents' brief is filed	
(B) 3-12-75	4—Respondent's motion for substitution of party (m-12)	

DATE	FILINGS—PROCEEDINGS	Filed
(B) 3-12-75	7—Respondent's typewritten brief (m-12)	
(R) 3-18-75	Order per Wright ACJ, granting respondents' motion for substitution of party respondent and the Clerk is directed to substitute the U.S.N.R.C. for the U.S.A.E. commission as a party respondent in this case	
(K) 3-26-75	4—Motion of the State of New York for leave to file brief as Amicus Curiae (OK RB) (m-20)	
(K) 3-31-75	7—Petitioners' Reply Brief (m-28)	
(K) 4- 7-75	4—Intervenors' response to motion by State of New York for leave to file amicus curiae brief, time having expired (m-4)	
(K) 4- 7-75	4—Respondents' reply to the State of New York's motion for leave to file brief as amicus curiae (m-4)	
(R) 4- 9-75	Order per Wright ACJ, granting motion of the State of New York for leave to file a brief as amicus curiae out of time and the Clerk is directed to file the brief of the state of New York as amicus curiae	
(R) 4- 9-75	25—Amicus curiae brief for State of New York (m-20)	
(K) 4- 9-75	4—Petitioners' motion for leave to correct errata sheet (m-9)	
(K) 4-11-75	7—Joint Appendix (Volumes I and II) (m-11)	
(R) 4-15-75	Clerk's order granting petitioners' motion for leave to correct errata sheet	
(G) 4-16-75	25—Petitioners' brief (m-17)	
(G) 4-16-75	25—Petitioners' reply brief (m-17)	
(R) 4-18-75	Order per Wright ACJ, sua sponte, that the order filed April 9th is amended by adding the following paragraph: Counsel for the parties, if they be so advised, may file answers to the amicus curiae brief within 20 days from the date of this order. Counsel for the parties shall provide 15 copies of their respective answers to the Court for filing	

DATE	FILINGS—PROCEEDINGS	Filed
(K) 4-28-75	15—Intervenors' Brief (m-25)	
(K) 4-28-75	15—Respondents' Brief (m-25)	
(G) 5- 8-75	15—Intervenor's reply brief to State of New York's amicus curiae brief (m-7)	
(G) 5- 9-75	15—Respondents' reply to brief for State of New York as amicus curiae (m-8)	
(R) 5- 8-75	Clerk's order sua sponte, that this appeal is consolidated with appeal no. 74-1385 for oral argument; sua sponte, that the following times are allotted for oral argument; Petitioners in both cases—30 minutes (to be divided as they see fit) and Respondent —30 minutes	
(G) 5-14-75	Letter from petitioners' advising of additional authorities pursuant to Local Rule 8	
(K) 5-15-75	4—Joint motion for reconsideration of order consolidating oral arguments in Nos. 74-1385 and 74-1586 (m-14)	
(R) 5-22-75	Clerk's order denying motion for reconsideration; the Court will consider extending the time available to each side at argument if circumstances warrant	
(K) 5-22-75	4—Petitioner's motion for leave to allow three counsel to argue for petitioners (m-22)	
(R) 5-27-75	Argued before CJ Bazelon; George C. Edwards, Jr., CJ for the Sixth Circuit, sitting by designation; and Tamm, CJ	
(R) 5-27-75	Per Curiam order granting motion for leave to permit three counsel to argue for petitioners; CJ Bazelon; Edwards, U.S. CJ for the Sixth Circuit, sitting by designation and Tamm, CJ	
(K) 5-29-75	Letter from Petitioner advising of additional authorities pursuant to Local Rule 8(g)	
(K) 6- 3-75	Letter from Intervenor advising of additional authorities pursuant to Local Rule 8(g)	
(K) 7- 8-75	Return receipt from George C. Freeman for order of 5/27/75	

DATE	FILINGS—PROCEEDINGS	Filed
(K) 9-24-75	Letter from Petitioner advising of additional authorities pursuant to Local Rule 8(g)	
(H) 1-19-76	3—Environmental Survey of the Nuclear Fuel Cycle, lodged by appellee, USNRC per DMC	
7-21-76	Opinion for the Court filed by Chief Judge Bazelon.	
7-21-76	Separate statement of Chief Judge Bazelon.	
7-21-76	Separate statement filed by Circuit Judge Tamm, concurring in result.	
7-21-76	Judgment remanding case to the NRC.(n)	
(H) 8- 3-76	4—Respondents' motion to extend time to file petition for rehearing and/or suggestion for rehearing en banc to August 25, 1976 (m-2)	
(C) 8- 4-76	4—Motion of Baltimore Gas and Electric Co., et al. to extend time to file petition for rehearing to Aug. 25 (m-4)	
(C) 8- 6-76	4—Petitioners' opposition to motions to extend time to file petition for rehearing (m-5)	
(C) 8- 6-76	4—Petitioners' motion for issuance of mandate forthwith (m-5)	
(C) 8-11-76	4—Respondents' motion for stay of mandate (m-11)	
(K) 8-20-76	Per Curiam order that the motions of intervenor-appellee Vermont Yankee Nuclear Power Corp., of intervenors Baltimore Gas and Electric Co., et al and respondents NRC and US to extend time to file petitions for rehearing to August 25, 1976 are granted; CJ Bazelon; Edwards, U.S. Circuit Judge for the Sixth Circuit, sitting by designation and Tamm, CJ	
(K) 8-23-76	Per Curiam order that Petitioners' motion for issuance of mandate forthwith is denied; CJ Bazelon; Edwards, U.S. Circuit Judge for the Sixth Circuit, sitting by designation and Tamm, CJ	
(K) 8-23-76	Per Curiam order that respondents' US and NRC motion for stay of mandate pending decision on their motion to extend time to file petition for rehearing and/or suggestion for rehearing en banc is granted; CJ Bazelon; Edwards, U.S. Circuit Judge for the Sixth Circuit, sitting by designation and Tamm, CJ	

DATE	FILINGS—PROCEEDINGS	Filed
(K) 8-23-76	4—Respondents' motion for stay of mandate and correction of opinion (m-20) (Ok GF)	
(G) 8-25-76	4—Petitioners' opposition to motion and stay and correction of opinion (m-24)	
(C) 8-25-76	4—Intervenors' (Baltimore Gas & Electric Co., et al.) motion for stay of mandate (m-25)	
(C) 8-26-76	4—Motion of Robert Jeffers, David Hensler, Patrick Raher & George Mayo, Jr., to withdraw as counsel for petitioner NRDC (m-26)	
(G) 8-30-76	Return receipt from counsel for intervenor in No. 74-1586 for certified copy of order filed August 20, 1976	
(G) 9- 1-76	4—Respondents' reply to opposition to motion for stay of mandate (m-30)	
(G) 9-17-76	4—Respondents' motion for further stay of mandate (m-15)	
(C) 9-23-76	Notice from Clerk, Supreme Court that writ of certiorari was filed on Sept. 21 in SC No. 76-419	
(K) 10- 7-76	Per Curiam order that the motion of Robert M. Jeffers, David J. Hensler, Patrick M. Raher and George W. Mayo, Jr., to withdraw their appearances as counsel for petitioner Natural Resources Defense Council, Inc., is granted; CJ Bazelon; Edwards, U.S. Circuit Judge for the Sixth Circuit, sitting by designation and Tamm, CJ	
(K) 10- 8-76	Per Curiam order that the Clerk is directed to file the document titled "Stipulation" which had been lodged in the Clerk's Office by petitioners on 8/16/76, and that the motions for stay of mandate are granted, and the Clerk is directed not to issue the mandate herein prior to October 31, 1976, on condition that the United States Nuclear Regulatory Commission shall make any licenses granted between July 21, 1976 and such time when the mandate is issued subject to the outcome of the proceedings herein; CJ Bazelon; Edwards, U.S. Circuit Judge for the Sixth Circuit, sitting by designation and Tamm, CJ	

DATE	FILINGS—PROCEEDINGS	Filed
(K)10- 8-76	4—Stipulation of Petitioners dated 8/16/76	
(K)10- 8-76	4—Petitioner's (in #74-1586) opposition to motion of Intervenor, Baltimore Gas & Electric Co. for stay of mandate (m-7)	
(K)10- 8-76	Per Curiam order that respondents' motion for correction of this Court's opinion dated July 21, 1976, is granted in part, and the opinion dated July 21, 1976 is amended as follows: On page 34, delete lines 3-5. On page 34, delete footnote 53 and renumber all succeeding footnotes. On page 41, delete the following from footnote 59: "In this case the board members asked no questions whatsoever of Dr. Pittmann. *See supra* note 53." In all other respects, respondents motion for correction is denied; CJ Bazelon; Edwards, U.S. Circuit Judge for the Sixth Circuit, sitting by designation and Tamm, CJ	
(C)10-15-76	Copy of letter from Clerk, Supreme Court extending time to file petition for writ of certiorari in No. A-285 to Nov. 18	
(C)10-26-76	Notice of filing of certiorari in SC No. 76-548 on Oct. 19	
(H)11- 8-76	4—Letter from NRC advising of additional authorities pursuant to Local Rule 8(g)	
(H)11-19-76	4—Petitioner's motion for clarification of the stay of mandate issued on October 8, 1976 (m-19)	
(H)11-29-76	4—Respondents' motion to extend time to file response to motion for clarification of the stay of mandate filed on October 8, 1976	
(R) 2-17-77	Per Curiam order that the motion of respondents U.S. Nuclear Regulatory Comm. and USA and of Intervenors Vermont Yankee Nuclear Power Corp. and Baltimore Gas and Electric Co. is granted and the Clerk is directed to file the response to petitioners' motion for clarification; the petitioners' motion for clarification is denied; CJ Bazelon; Edwards, U.S. CJ for the Sixth Circuit, sitting by designation; and Tamm, CJ	

DATE	FILINGS—PROCEEDINGS	Filed
(R) 2-17-77	4—Opposition to intervenors Baltimore Gas and Electric Co., et al to petitioners' motion for clarification of the stay of mandate (m-6)	
(C) 2-17-77	4—NRC's response to petitioners' motion for clarification of stay of mandate (m-Dec. 6) (OK, GF)	
(C) 3- 3-77	Certified copy of order from Clerk, Supreme Court granting writ of certiorari on Feb. 22 in SC No. 76-419	
(C) 4- 4-77	Letter from Clerk, Supreme Court dated 4/1/77 requesting that the record be certified and transmitted in SC No. 76-419	
(K) 4-29-77	Clerk's order that the Clerk is directed to certify and transmit the following to the Supreme Court: 1. Certified Index to Record filed in #74-1385 on May 6, 1974. 2. Certified Index to the Record filed in #74-1586 on July 17, 1974. 3. Joint appendix filed in #74-1385 on February 27, 1975. 4. Volumes I and II of Joint Appendix filed in #74-1586 on April 11, 1975. 5. Order of May 8, 1975 consolidating appeal Nos. 74-1385 and 74-1586 for oral argument. 6. This Court's opinion and judgment dated July 21, 1976. 7. Order of October 8, 1976 directing Clerk to file the lodged document titled "stipulation", and granting the motions for stay of mandate. 8. Stipulation of Petitioners dated August 16, 1976. 9. Order of October 8, 1976 amending this Court's opinion and 10. A Copy of this order.	
(K) 4-29-77	Certified copy of the above order with the Certified Index in #74-1385 and 74-1586 sent to Clerk, US Supreme Court	
(C) 4-29-77	Certified record of pleadings prepared and hand delivered to Supreme Court.	
(K) 5- 2-77	Receipt returned from Clerk, US Supreme Court for the certified index to record filed July 17, 1974 in this case.	
(A) 5-17-78	1—Certified copy of order from Clerk, Supreme Court granting petition for writ of certiorari on April 17, 1978 in SC No. 76-548	

DATE	FILINGS—PROCEEDINGS	Filed
(A) 5-17-78	1—Certified copy of order from Clerk, Supreme Court that judgment of this court is vacated with costs, and that this cause is remanded to this court for further consideration in light of *Vermont Yankee Nuclear Power Corp.* v. *Natural Resources Defense Council.* It is further ordered that Baltimore Gas and Electric Co., et al. recover from NRDC, Inc., et al. One Hundred Dollars ($100) for their costs herein expended in SC No. 76-548 (dated April 17, 1978)	
(A) 6- 2-78	4—Respondent's (NRC) motion to dismiss petitions for review (m-2)	
(C) 6- 7-78	Clerk's order that the parties are requested to submit memorandum (See Nos. 1-7 of order); Respondents' and intervenors' supporting respondents memorandum due June 27th; Petitioners' responsive memorandum due July 17th and at that time petitioners in 74-1385 and 74-1586 should respond to NRC's motion to dismiss; The time for filing the Certified Index in 77-1448 is extended until further order of this Court	
(C) 6-27-78	4—Respondent's (NRC) response to order of 6/7/78 (m-27)	
(C) 6-27-78	4—Amici Curiae (Con. Ed., et al.) response to order of 6/7/78 (m-27)	
(C) 6-27-78	4—Intervenor's (BG&E) response to order of 6/7/78 (m-27)	
(C) 6-29-78	Clerk's order, sua sponte, that this Court's order of 6/7/78 is amended to require that an original and 8 copies of all future pleadings be submitted; In all other respects, the order filed on 6/7/78 remains unchanged	
(T) 7-14-78	Record returned from Clerk, Supreme Court	
(T) 7-17-78	8—Petitioner's (NRDC) response to order of June 7, 1978, and response to motions to dismiss (m-14)	
(T) 7-17-78	8—Petitioner's (NRDC) motion to establish the record for review (m-14)	

DATE	FILINGS—PROCEEDINGS	Filed
(T) 7-21-78	9—NRC's motion to extend time to respond to NRDC's motion to establish the record for review (m-21)	
(T) 7-24-78	Clerk's order granting NRC's motion to extend time to respond to NRDC's motion to establish the record for review to and including July 28, 1978	
(T) 7-25-78	9—Opposition of Baltimore Gas and Electric Company, et al to NRDC's motion to establish the record for review (m-24)	
(T) 7-28-78	9—NRC's opposition to motion to establish the record for review (m-28)	
(T) 9-21-78	9—Status letter (m-20)	
(E) 11-16-78	Per Curiam order that this case be held in abeyance pending the issuance of a final fuel cycle rule. Commission counsel should report to the court at 90 day intervals on the status of the rulemaking; Bazelon and Tamm, CJ's and Edwards, US CJ for the Sixth Circuit. Judge Bazelon reserves the right to file a statement in connection with this order.	
(T) 12- 4-78	9—Status letter (m-1)	
(D) 3-16-79	9—NRC's Status Letter (m-13)	
(D) 5-16-79	9—NRC's Status Letter (m-15)	
(T) 6- 1-79	9—NRC's status letter (m-30)	
(C) 8- 9-79	9—NRC's status letter (m-2)	
(C) 10- 4-79	9—NRDC's request for commencement and expedited completion of review (m-4)	
(D) 10-15-79	4—Intervenor's (Baltimore Gas & Elec. Co., et al.) opposition to NRDC request for commencement and expedited completion of review (m-15)	
(D) 10-23-79	4—NRC's motion for leave to file opposition to NRDC's request for commencement and expedited completion of review, time having expired (m-23)	

DATE	FILINGS—PROCEEDINGS	Filed
(T)11-27-79	Clerk's order: The Court request [*sic*] concise responses to the following questions (1-5, see order) from petitioners and intervenors within 15 days of this order; respondents and intervenors shall similarly file their responses to the questions 10 days thereafter; (1) the NRC's motion to dismiss 74-1385 and 74-1586 and (2) the NRDC's motion to establish the record in 74-1385, 74-1586 and 77-1448 are denied without prejudice; petitioners' motions to enforce the mandate and injunctive relief in 73-1776 and 73-1857 (filed March 20, 1978) are denied and the mandate is recalled; (1) the motions of Tennessee Valley Authority and BG&E, et al for leave to intervene in 79-2110 and 79-2131 and (2) the motion of the State of Wisconsin for leave to intervene in 79-2110 are granted; NRC's motion for leave to file its opposition to the NRDC's request for commencement and expedited review in 74-1385, 74-1586 and 77-1448 is granted; NRC's motion for an extension of time in which to reply to NRDC's motion to hold 79-2131 in abeyance is denied but treated as the NRC's response to the NRDC motion; the briefing in 79-2110 and 79-2131 is deferred until subsequent Court order; and that ruling on NRDC's motion to commence and expedite review in 74-1385, 74-1586 and 77-1448 and motion to hold in abeyance No. 79-2131 is deferred pending further Court order	
(D)12-12-79	9—Petitioners' response to court's order of 11-27-79 (m-27)	
(D)12-26-79	4—Respondent's (NRC) response to court's order of 11-27-79 (m-26)	
(D)12-26-79	4—Intervenor's response to court's order of 11-27-79 (m-26)	
(T)12-28-79	4—Response of Commonwealth Edison, et al. to court's order of 11/27/79 (m-26)	

DATE	FILINGS—PROCEEDINGS	Filed
(E) 2-11-80	Per Curiam order that Nos. 74-1586, 77-1448, 79-2110 & 79-2131 are consolidated for all purposes and the following schedule is established: 1) within 20 days from the date of this order, the parties shall file a stipulation as to the record. The parties should at that time identify those materials as to which they cannot agree to include in the record. b) within 30 days thereafter, petitioners and intervenors in support of petitioners shall file and serve their brief, c) within 30 days thereafter respondent's and supporting intervenor's briefs, d) within 14 days thereafter, petitioners and supporting intervenor's briefs reply brief and e) within 14 days thereafter, petitioners shall file their appendices. Petitioners need not resubmit materials previously filed as the appendix for No. 74-1586 and these cases will be scheduled for argument as soon after that time as the business of the Court permits; SCJ Bazelon, CJ Edwards, USCA for Sixth Circuit and Tamm, CJ	
(D) 2-19-80	9—Motion of Vermont Yankee Nuclear Power Corporation for clarification of order of 2-11-80 (m-15)	
(D) 3- 3-80	9—Stipulation As to the Record (n-27)	
(E) 3-12-80	Per Curiam order granting intervenor's motion for clarification of order of 2-11-80 and that order is amended to provide that the filing requirements set forth in that order have no application to No. 74-1385—NRDC, Inc., et al. v. US NRC, et al.; SCJ Bazelon, Edwards, USCA Judge for Sixth Circuit and Tamm, CJ	
(T) 4- 2-80	4—Petitioner's brief (m-2)	
(D) 5- 5-80	4—Respondents' motion for leave to file motion to extend time to file brief (m-2)	
(D) 5- 7-80	25—Intervenors' (Baltimore Gas & Electric Company, et al) brief (m-5)	
(D) 5-13-80	4—Amicus Curiae (Commonwealth Edison Company, et al.) brief (m-9)	

DATE	FILINGS—PROCEEDINGS	Filed
(E) 5-21-80	Per Curiam order granting respondent's motion for leave to file motion to extend time to file brief and granting motion to May 21, 1980; SCJ Bazelon, Edwards, US CJ for the Sixth Circuit and Tamm, CJ	
(E) 5-21-80	4—Respondent's motion to extend time to file brief —granted	
(E) 5-21-80	4—Respondent's brief (m-9)	
(C) 5-30-80	4—Motion of amicus curiae, Consolidated Edison Co. of New York, for leave to withdraw as a party (m-30)	
(C) 5-30-80	4—Petitioner's motion to extend time to file supplemental joint appendix to 6/25/80 (m-20)	
(C) 5-30-80	4—Petitioner's reply brief (m-27)	
(B) 6-12-80	Per Curiam order granting motion of Consolidated Edison Company of New York for leave to withdraw; and the Clerk is directed to note the docket to reflect that movant Consolidated Edison Company of New York has been authorized to withdraw from Appeal Nos. 74-1586 and 77-1448 as amicus curiae and as intervenor, respectively; SCJ Bazelon, Tamm, CJ, and Edwards, CJ, USCA for the Sixth Circuit	
(E) 6-18-80	Per Curiam order granting petitioner's motion to extend time to file supplemental joint appendix to June 25, 1980; SCJ Bazelon, Tamm, CJ and Edwards, Chief Judge, USCA for Sixth Circuit	
(D) 6-25-80	4—Petitioner's motion to extend time to file supplemental joint appendix to 7-10-80 (m-25)	
(B) 7-11-80	Per Curiam order granting petitioner's motion to extend time and the time within which petitions [sic] may file a supplemental joint appendix is extended to 7-10-80; SCJ Bazelon, Edwards, Judge, US Court of Appeals for the Sixth Circuit, and Tamm, CJ	
(B) 7-11-80	7—Petitioner's supplemental joint appendix, Vols. I thru VI (m-10)	

DATE	FILINGS—PROCEEDINGS	Filed
(D) 7-24-80	15—Petitioners' brief (m-24)	
(D) 7-24-80	15—Petitioners' reply brief (m-24)	
(D) 7-24-80	15—Respondent's brief (m-24)	
(T) 7-28-80	15—Brief of amicus curiae (Commonwealth Edison Company, et al) (m-24)	
(T) 7-28-80	25—Intervenor's (Baltimore Gas & Electric Company, et al) brief (m-25)	
(B) 8-13-80	Per Curiam order that the parties are requested to file simultaneous memoranda by noon, Sept. 5, 1980, addressing the following questions propounded by the Court. Responses should be brief and make precise citations to the administrative record where appropriate, (see order for further information); No Judges disclosed	
(T) 9- 5-80	4—Intervenors' response to Court's order of August 13, 1980 (m-5)	
(T) 9- 5-80	4—NRC's response to the Court's order of August 13, 1980 (m-5)	
(T) 9- 5-80	4—Petitioners' response to the Court's order of August 13, 1980 (m-5)	
(C) 9-12-80	Clerk's order, sua sponte, that the following times are allotted for oral argument: Petitioners—45 minutes; Respondent & intervenors—45 minutes; Counsel are directed to allocate this time among themselves. Leave is granted for more than two counsel to argue on each side	
(B) 9-17-80	Argued before SCJ Bazelon * and Wilkey, CJ, and CJ George Edwards, Jr., USCA for the Sixth Circuit	
(C) 3-13-81	4—Letter dated 3/12/81 from NRC advising of status (m-12)	
(B) 10- 7-81	Per Curiam order, sua sponte, that the Nuclear Regulatory Commission advise, as soon as possible, as to when the Commission expects to promulgate the Narrative Explanation of Table S-3; SCJ Bazelon, George C. Edwards, Jr., Chief Judge, USCA for the Sixth Circuit and Wilkey, CJ	

DATE	FILINGS—PROCEEDINGS	Filed
(V) 10-19-81	4—Letter from counsel for NRC advising of status pursuant to order of 10/07/81 (m-16)	
(S) 4-27-82	Opinion for the Court filed by SCJ Bazelon	
(S) 4-27-82	Opinion concurring in part and dissenting in part filed by CJ George Edwards	
(S) 4-27-82	Dissenting opinion filed by CJ Wilkey	
(S) 4-27-82	Judgment that the orders of the NRC under review are vacated and the cases are remanded for further proceedings consistent with the opinion for the Court	
(G) 5-11-82	4—Petitioners' bill of costs (m-11)	
(V) 5-27-82	Per Curiam order that the time for filing petitions for rehearing and/or suggestions for rehearing en banc is established as 45 days from the date of judgment for all parties; SCJ Bazelon, CJ George C. Edwards, Jr., USCA for the 6th Circuit and Wilkey, CJ	
(B) 5-27-82	4—Petitioner's (NRDC) motion for entry of order awarding reasonable attorney's fees (m-27)	
(B) 5-27-82	4—Petitioner's (NRDC) motion to hold in abeyance and request for permission to supplement (m-27)	
(B) 6-11-82	15—Amici Curiaes' (Commonwealth Edison, et al.) petition for rehearing and suggestion for rehearing en banc (m-11)	
(B) 6-11-82	15—Intervenor's (Baltimore Gas) suggestion for rehearing en banc (m-11)	
(B) 6-11-82	15—Respondent's petition for rehearing and suggestion for rehearing en banc (m-11)	
(V) 6-29-82	Per Curiam order that petitioner's (NRDC, Inc.) motion to hold in abeyance and request for permission to supplement is granted; SCJ Bazelon, CJ George C. Edwards, Jr., USCA for the Sixth Circuit and Wilkey, CJ	

DATE	FILINGS—PROCEEDINGS	Filed
(V) 6-30-82	Per Curiam order that the petitions for rehearing filed by respondents and by intervenors Commonwealth Edison Company, et al. and Pacific Legal Foundation are denied; SCJ Bazelon, CJ George C. Edwards, Jr., USCA for the 6th Circuit and Wilkey, CJ (Statement of SCJ Bazelon as to why he voted to deny rehearing, attached, Judge Wilkey's position is set forth in his statement attached to the en banc order entered this date)	
(V) 6-30-82	Per Curiam order, en banc, that the suggestions for rehearing en banc filed by respondents and by intervenors Commonwealth Edison Company, et al., Pacific Legal Foundation, and Baltimore Gas & Electric Company, et al. are denied; CJ Robinson, SCJ Bazelon, Wright (who did not participate), CJ, CJ George C. Edwards, Jr., USCA for the 6th Circuit, Wilkey, Wald, Mikva and Ginsburg, CJs (Judge Wilkey does not ask for en banc consideration because he believes nothing should delay consideration of this case by the Supreme Court. Judges Tamm, MacKinnon, Harry T. Edwards and Bork are recused)	
(C) 7- 6-82	4—Intervenors' (BG&E) motion for stay of mandate (m-11)	
(C) 7- 7-82	4—Respondents' motion to stay issuance of mandate (m-7)	
(C) 7- 7-82	4—Intervenors' (Comm. Ed, et al.) motion for stay of mandate (m-7)	
(C) 7-13-82	9—NRDC's opposition to motions to stay issuance of mandate or motion for other appropriate relief (m-13)	
(S) 7-20-82	Orders of 6-30-82 issued in printed form, to be published	
(B) 7-19-82	4—Respondent's reply to the NRDC's opposition to the motion for stay of mandate (m-19)	
(C) 7-21-82	4—Intervenors' (BG&E, et al.) reply to NRDC's opposition to motion for stay of mandate (m-21)	

DATE	FILINGS—PROCEEDINGS	Filed
(C) 9- 1-82	Per curiam order granting motions for stay of mandate and Clerk is directed not to issue the mandate herein for a period of 30 days from the date of this order; Bazelon, SCJ; Edwards, Chief Judge, USCA for the 6th Circuit and Wilkey, CJ	
(T) 9-28-82	Letter from Clerk, Supreme Court that petition for writ of certiorari was filed on 09-24-82 in SC No. 82-524 (Baltimore Gas and Electric Co., et al.)	
(T) 9-30-82	Notification from Clerk, Supreme Court that petition for writ of certiorari was filed on 09-28-82 in SC No. 82-551 (Commonwealth Edison Co., et al.)	
(T) 9-30-82	Notification from Clerk, Supreme Court that petition for writ of certiorari was filed on 09-27-82 in SC No. 82-545 (U.S. NRC, et al.)	
(S)10- 6-82	Per Curiam order by the Court sua sponte that the opinion concurring in part and dissenting in part filed by Chief Judge George Edwards on 4-27-82 in this case is hereby amended (see order for details)	
(T)11-10-82	4—Letter dated 11-08-82 from counsel for NRC enclosing (15) copies of the Statement of Policy (m-8)	
(J)12- 2-82	Certified copy of order from Clerk, Supreme Court granting petition for writ of certiorari in SC No. 82-524 on 11-29-82 (Baltimore Gas and Electric Co., et al.)	
(J)12- 2-82	Certified copy of order from Clerk, Supreme Court granting petition for writ of certiorari in SC No. 82-545 on 11-29-82 (U.S. NRC, et al.)	
(J)12- 2-82	Certified copy of order from Clerk, Supreme Court granting petition for writ of certiorari in SC No. 82-551 on 11-29-82 (Commonwealth Edison Co., et al.)	

[DOCKET ENTRIES IN THE COURT BELOW
IN
DOCKET NO. 77-1448]

GENERAL DOCKET

UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

DATE	FILINGS—PROCEEDINGS	Filed
(C) 5-13-77	4—Petitioner's petition for review of an order of the NRC (m-13)	
(C) 5-16-77	Certified copy of petitioner's petition for review of an order of the NRC was mailed to Attorney General and NRC by certified mail, return receipt requested	
(C) 6-13-77	4—Motion of Consolidated Edison Co. of NY, Inc., et al. for leave to intervene (m-13)	
(C) 6-13-77	4—Motion of Baltimore Gas and Electric Co., et al. for leave to intervene (m-13)	
(C) 6-13-77	4—Motion of Commonwealth Edison Co. for leave to intervene (m-13)	
(C) 6-13-77	4—Motion of Pacific Legal Foundation for leave to intervene (m-13)	
(D) 6-27-77	4—Respondent's motion to extend time to file certified index to July 27 (m-23)	
(K) 6-29-77	Clerk's order granting motions of Consolidated Edison Company of New York, Inc., et al., Baltimore Gas and Electric Company, et al., Commonwealth Edison Company and Pacific Legal Foundation for leave to intervene. Counsel for the intervenors are encouraged to file joint briefs wherever practicable and may participate in oral argument only to the extent allowable under Rule 12 of the General Rules of this Court.	
(K) 7- 6-77	4—Petitioner's motion to hold case in abeyance (m-5)	

DATE	FILINGS—PROCEEDINGS	Filed
(K) 7- 8-77	Clerk's order granting respondent's motion to extend time to file certified index to record to July 27, 1977	
(G) 7-15-77	4—Respondent's (NRC) response to motion to hold petition for review in abeyance (m-13)	
(K) 7-21-77	Clerk's order granting petitioner's motion to hold petition for review in abeyance, and the time for filing the certified record herein is extended until 30 days after final decision by the Supreme Court of the United States in *Natural Resources Defense Council* v. *Nuclear Regulatory Commission*, —— U.S. App. D.C. ——, 547 F.2d 633 (1976), *cert. granted*, 45 U.S.L.W. 3554 (February 22, 1977).	
(H) 8- 3-77	Receipt mail receipt returned from NRC for the petition for review	
(C) 6- 7-78	Clerk's order that the parties are requested to submit memorandum (See Nos. 1-7 of order); Respondents' and intervenors' supporting respondents memorandum due June 27th; Petitioners' responsive memorandum due July 17th and at that time petitioners in 74-1385 and 74-1586 should respond to NRC's motion to dismiss; The time for filing the Certified Index in 77-1448 is extended until further order of this Court	
(C) 6-27-78	4—Intervenor's (Pacific Legal Foundation) response to order of 6/7/78 (m-27)	
(C) 6-27-78	4—Intervenor's (BG& E Co., et al.) response to order of 6/7/78 (m-27)	
(C) 6-27-78	4—Intervenor's (Con. Ed.) response to order of 6/7/78 (m-27)	
(C) 6-27-78	4—Respondent's (NRC) response to order of 6/7/78 (m-27)	
(C) 6-29-78	Clerk's order, sua sponte, that this Court's order of 6/7/78 is amended to require that an original and 8 copies of all future pleadings be submitted; In all other respects, the order filed on 6/7/78 remains unchanged	

DATE	FILINGS—PROCEEDINGS	Filed
(T) 7-17-78	8—Petitioner's response to order of June 7, 1978, and response to motions to dismiss (m-14)	
(T) 7-17-78	8—Petitioner's motion to establish the record for review (m-14)	
(T) 7-21-78	9—NRC's motion to extend time to respond to NRDC motion to establish the record for review (m-21)	
(T) 7-24-78	Clerk's order granting NRC's motion to extend time to file response to NRDC's motion to establish the record for review to and including July 28, 1978	
(T) 7-28-78	9—NRC's opposition to motion to establish the record for review (m-28)	
(T) 9-21-78	9—NRC status letter (m-20)	
(E)11-20-78	Order per CJ Wright that this case be held in abeyance pending the issuance of a final fuel cycle rule. Commission counsel should report to the Court on the status of the rulemaking in accordance with the schedule established in Nos. 73-1776 and 74-1385 and the cases consolidated with them	
(T)12- 4-78	9—Status letter (m-1)	
(D) 3-16-79	9—NRC's status letter (m-13)	
(D) 5-16-79	9—NRC's Status Letter (m-15)	
(T) 6- 1-79	9—NRC's status letter (m-30)	
(C) 8- 9-79	9—NRC's status letter (m-2)	
(C)10- 4-79	9—NRDC's request for commencement and expedited completion of review (m-4)	
(D)10-15-79	4—Intervenor's (Baltimore Gas & Elec. Co., et al.) opposition to NRDC request for commencement and expedited completion of review (m-15)	
(D)10-23-79	4—NRC's motion for leave to file opposition to NRDC's request for commencement and expedited completion of review, time having expired (m-23)	

DATE	FILINGS—PROCEEDINGS	Filed
(T) 11-27-79	Clerk's order: The Court request concise responses to the following questions (1-5, see order) from petitioners and intervenors within 15 days of this order; respondents and intervenors shall similarly file their responses to the questions 10 days thereafter; (1) the NRC's motion to dismiss 74-1385 and 74-1586 and (2) the NRDC's motion to establish the record in 74-1385, 74-1586 and 77-1448 are denied without prejudice; Petitioners' motions to enforce the mandate and injunctive relief in 73-1776 and 73-1867 (filed March 20, 1978[)] are denied and the mandate is recalled; (1) the motions of Tennessee Valley Authority and BG&E, et al. for leave to intervene in 79-2110 and 79-2131 and (2) the motion of the State of Wisconsin for leave to intervene in 79-2110 are granted; NRC's motion for leave to file its opposition to the NRDC's request for commencement and expedited completion of review in 74-1385, 74-1586 and 77-1448 is granted; NRC's motion for an extension of time in which to reply to NRDC's motion to hold 79-2131 in abeyance is denied but treated as the NRC's response to the NRDC motion; the briefing in 79-2110 and 79-2131 is deferred until subsequent Court order; and the ruling on NRDC's motion to commence and expedite review in 74-1385, 74-1586 and 77-1448 and motion to hold in abeyance No. 79-2131 is deferred pending further Court order	
(D) 12- 3-79	Certified Index to Record (n-10)	
(D) 12-12-79	9—Petitioners' response to court's order of 11-27-79 (m-27)	
(D) 12-20-79	4—Intervenor's (Pacific Legal Foundation) response to court's order of 11-27-79 (m-20)	
(D) 12-26-79	4—Respondent's (NRC) response to court's order of 11-27-79 (m-26)	
(D) 12-26-79	4—Intervenor's (Baltimore Gas & Elec. Co., et al.) response to court's order of 11-27-79 (m-26)	
(T) 12-28-79	4—Response of Commonwealth Edison, et al. to court's order of 11/27/79 (m-26)	

DATE	FILINGS—PROCEEDINGS	Filed
(E) 2-11-80	Per Curiam order that Nos. 74-1586, 77-1448, 79-2110 & 79-2131 are consolidated for all purposes and the following schedule is established: 1) within 20 days from the date of this order, the parties shall file a stipulation as to the record. The parties should at that time identify those materials as to which they cannot agree to include in the record. b) within 30 days thereafter, petitioners and intervenors in support of petitioners shall file and serve their brief [*sic*], c) within 30 days thereafter respondent's and supporting intervenor's briefs, d) within 14 days thereafter, petitioners and supporting intervenor's reply briefs and e) within 14 days thereafter, petitioners shall file their appendices. Petitioners need not resubmit materials previously filed as the appendix for No. 74-1586 and these cases will be scheduled for argument as soon after that time as the business of the Court permits; SCJ Bazelon, CJ Edwards, USCA for Sixth Circuit & Tamm, CJ	
(D) 2-19-80	9—Motion of Vermont Yankee Nuclear Power Corporation for clarification of order of 2-11-80 (m-15)	
(D) 3- 3-80	9—Stipulation As to Record (n-27)	
(E) 3-12-80	Per Curiam order granting intervenor's motion for clarification of order of 2-11-80 and that order is amended to provide that the filing requirements set forth in that order have no application to No. 74-1385—NRDC, Inc., et al. v. US NRC, et al.; SCJ Bazelon, Edwards, USCA Judge for Sixth Circuit and Tamm, CJ	
(T) 4- 2-80	4—Petitioner's brief (m-2)	
(D) 5- 5-80	4—Respondents' motion for leave to file motion to extend time to file brief (m-2)	
(D) 5- 7-80	25—Intervenor's (Baltimore Gas & Elec. Co., et al.) brief (m-5)	
(D) 5- 9-80	15—Intervenor's (Pacific Legal Foundation) letter adopting brief of Commonwealth Edison, et al. (m-9)	

DATE	FILINGS—PROCEEDINGS	Filed
(D) 5-13-80	4—Intervenors' (Commonwealth Edisor Co., et al.) brief (m-9)	
(C) 5-21-80	Per Curiam order granting respondent's motion for leave to file motion to extend time to file brief and granting motion to May 21, 1980; SCJ Bazelon; Edwards, USCJ for the Sixth Circuit and Tamm, CJ	
(C) 5-21-80	4—Respondent's motion to extend time to file brief—granted	
(C) 5-21-80	4—Respondent's brief (m-9)	
(C) 5-30-80	4—Intervenor's (Consolidated Edison of New York, Inc.) motion for leave to withdraw as a party (m-30)	
(C) 5-30-80	4—Petitioner's motion to extend time to file supplemental joint appendix to 6/25/80 (m-30)	
(C) 5-30-80	4—Petitioner's reply brief (m-30)	
(B) 6-12-80	Per Curiam order granting motion of Consolidated Edison Company of New York for leave to withdraw; and the Clerk is directed to note the docket to reflect that movant Consolidated Edison Company of New York has been authorized to withdraw from Appeal Nos. 74-1586 and 77-1448 as amicus curiae and as intervenor, respectively; SCJ Bazelon, Tamm, CJ and Edwards, CJ, USCA for the Sixth Circuit	
(E) 6-18-80	Per Curiam order granting petitioner's motion to extend time to file supplemental joint appendix to June 25, 1980; SCJ Bazelon, Tamm, CJ and Edwards, Chief Judge, USCA for Sixth Circuit	
(D) 6-25-80	4—Petitioner's motion to extend time to file supplemental joint appendix to 7-10-80 (m-25)	
(B) 7-11-80	Per Curiam order granting petitioner's motion to extend time and the time within which petitions may file a supplemental joint appendix is extended to 7-10-80; SCJ Bazelon, Edwards, Judge, US Court of Appeals for the Sixth Circuit, and Tamm, CJ	

DATE	FILINGS—PROCEEDINGS	Filed
(B) 7-11-80	7—Petitioner's supplemental joint appendix, Vols. I thru VI (m-10)	
(D) 7-24-80	15—Petitioners' brief (m-24)	
(D) 7-24-80	15—Petitioners' reply brief (m-24)	
(D) 7-24-80	15—Respondent's brief (m-24)	
(T) 7-28-80	15—Intervenors' (Commonwealth Edison Company, et al) brief (m-24)	
(T) 7-28-80	25—Intervenors' (Baltimore Gas & Electric Company, et al) brief (m-25)	
(B) 8-13-80	Per Curiam order that the parties are requested to file simultaneous memoranda by noon, Sept. 5, 1980, addressing the following questions propounded by the Court. Responses should be brief and make precise citations to the administrative record where appropriate, (see order for further information) ; No Judges disclosed	
(T) 9- 5-80	4—Intervenors' (Baltimore Gas) response to the Court's order of August 13, 1980 (m-5)	
(T) 9- 5-80	4—NRC's response to the Court's order of August 13, 1980 (m-5)	
(T) 9- 5-80	4—Petitioners' response to the Court's order of August 13, 1980 (m-5)	
(T) 9- 5-80	15—Intervenors' (Commonwealth Edison) response to the Court's order of August 13, 1980 (m-5)	
(T) 9-10-80	Letter from counsel for Pacific Legal Foundation advising that they will not present oral argument and with respect to the Court's order of August 13, 1980 they join in the response submitted by Commonwealth Edison, et al.	
(C) 9-12-80	Clerk's order, sua sponte, that the following times are allotted for oral argument: Petitioners—45 minutes; Respondent & Intervenors—45 minutes; Counsel are directed to allocate this time among themselves. Leave is granted for more than two counsel to argue on each side	

DATE	FILINGS—PROCEEDINGS	Filed
(B) 9-17-80	Argued before SCJ Bazelon * and Wilkey, CJ, and CJ George Edwards, Jr., USCA for the Sixth Circuit	
(C) 3-13-81	4—Letter dated 3/12/81 from NRC advising of status (m-12)	
(B) 10- 7-81	Per Curiam order, sua sponte, that the Nuclear Regulatory Commission advise, as soon as possible, as to when the Commission expects to promulgate the Narrative Explanation of Table S-3; SCJ Bazelon, George C. Edwards, Chief Judge, USCA for the Sixth Circuit and Wilkey, CJ	
(V) 10-19-81	4—Letter from counsel for NRC advising of status pursuant to order of 10/07/81 (m-16)	
(S) 4-27-82	Opinion for the Court filed by SCJ Bazelon	
(S) 4-27-82	Opinion concurring in part and dissenting in part filed by CJ George Edwards	
(S) 4-27-82	Dissenting opinion filed by CJ Wilkey	
(S) 4-27-82	Judgment that the orders of the NRC under review are vacated and the cases are remanded for further proceedings consistent with the opinion of the Court	
(C) 5- 7-82	4—Motion of Commonwealth Edison Co., et al, as intervenors to extend time to file petition for rehearing or suggestion for rehearing en banc (m-7)	
(G) 5-11-82	4—Petitioner's bill of costs (m-11)	
(V) 5-27-82	Per Curiam order that the time for filing petitions for rehearing and/or suggestions for rehearing en banc is established as 45 days from the date of judgment for all parties; SCJ Bazelon, CJ George C. Edwards, Jr., USCA for the 6th Circuit and Wilkey, CJ	
(B) 5-27-82	4—Petitioner's (NRDC) motion for entry of order awarding reasonable attorney's fees (m-27)	
(B) 5-27-82	4—Petitioner's (NRDC) motion to hold in abeyance and request for permission to supplement (m-27)	

DATE	FILINGS—PROCEEDINGS	Filed
(B) 6-11-82	15—Intervenors' (Commonwealth Edison, et al.) petition for rehearing and suggestion for rehearing en banc (m-11)	
(B) 6-11-82	15—Intervenor's (Baltimore Gas) suggestion for rehearing en banc (m-11)	
(B) 6-11-82	15—Intervenor's (Pacific Legal Foundation) petition for rehearing with suggestion for rehearing en banc (m-11)	
(B) 6-11-82	15—Respondent's petition for rehearing and suggestion for rehearing en banc (m-11)	
(V) 6-29-82	Per Curiam order that petitioner's (NRDC, Inc.) motion to hold in abeyance and request for permission to supplement is granted; SCJ Bazelon, CJ George C. Edwards, Jr., USCA for the 6th Circuit and Wilkey, CJ	
(V) 6-30-82	Per Curiam order that the petitions for rehearing filed by respondents and by intervenors Commonwealth Edison Company, et al. and Pacific Legal Foundation are denied; SCJ Bazelon, CJ George C. Edwards, Jr., USCA for the 6th Circuit and Wilkey, CJ (Statement of SCJ Bazelon as to why he voted to deny rehearing, attached. Judge Wilkey's position is set forth in his statement attached to the en banc order entered this date)	
(V) 6-30-82	Per Curiam order, en banc, that the suggestions for rehearing en banc filed by respondents and by intervenors Commonwealth Edison Company, et al, Pacific Legal Foundation and Baltimore Gas & Electric Company, et al. are denied; CJ Robinson, SCJ Bazelon, Wright (who did not participate), CJ, CJ George C. Edwards, Jr., USCA for the 6th Circuit, Wilkey, Wald, Mikva and Ginsburg, CJs (Judge Wilkey does not ask for en banc consideration because he believes nothing should delay consideration of this case by the Supreme Court. Judges Tamm, MacKinnon, Harry T. Edwards and Bork are recused)	
(C) 7- 6-82	4—Intervenor's (BG&E) motion for stay of mandate (m-11)	

DATE	FILINGS—PROCEEDINGS	Filed
(C) 7- 7-82	4—Respondents' motion to stay issuance of mandate (m-7)	
(C) 7- 7-82	4—Intervenors' (Comm. Ed., et al.) motion for stay of mandate (m-7)	
(C) 7-13-82	9—NRDC's opposition to motions to stay issuance of mandate or motion for other appropriate relief (m-13)	
(S) 7-20-82	Orders of 6-30-82 issued in printed form	
(B) 7-19-82	4—Respondent's reply to the NRDC's opposition to the motion for stay of mandate (m-19)	
(C) 7-21-82	4—Intervenors' (BG&E, et al.) reply to NRDC's opposition to motions for stay of mandate (m-21)	
(C) 9- 1-82	Per Curiam order granting motions for stay of mandate and Clerk is directed not to issue the mandate herein for a period of 30 days from the date of this order; Bazelon; SCJ; Edwards, Chief Judge, USCA for the 6th Circuit and Wilkey, CJ	
(T) 9-28-82	Letter from Clerk, Supreme Court that petition for writ of certiorari was filed on 09-24-82 in SC No. 82-524 (Baltimore Gas and Electric Co., et al.)	
(T) 9-30-82	Notification from Clerk, Supreme Court that petition for writ of certiorari was filed on 09-28-82 in SC No. 82-551 (Commonwealth Edison Co., et al.)	
(T) 9-30-82	Notification from Clerk, Supreme Court that petition for writ of certiorari was filed on 09-27-82 in SC No. 82-545 (U.S. NRC, et al.)	
(S)10- 6-82	Per Curiam order by the Court sua sponte that the opinion concurring in part and dissenting in part filed by Chief Judge George Edwards on 4-27-82 in this case is hereby amended (see order for details)	
(T)11-10-82	4—Letter dated 11-08-82 from counsel for NRC enclosing (15) copies of the Statement of Policy (m-8)	

DATE	FILINGS—PROCEEDINGS	Filed
(J)12- 2-82	Certified copy of order from Clerk, Supreme Court granting petition for writ of certiorari in SC No. 82-524 on 11-29-82 (Baltimore Gas and Electric Co., et al.)	
(J)12- 2-82	Certified copy of order from Clerk, Supreme Court granting petition for writ of certiorari in SC No. 82-545 on 11-29-82 (U.S. NRC, et al.)	
(J)12- 2-82	Certified copy of order from Clerk, Supreme Court granting petition for writ of certiorari in SC No. 82-551 on 11-29-82 (Commonwealth Edison Co., et al)	

**[DOCKET ENTRIES IN THE COURT BELOW
IN
DOCKET NO. 79-2110]**

GENERAL DOCKET

UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

DATE	FILINGS—PROCEEDINGS	Filed
(T) 9-20-79	4—Petitioner's petition for review of an order of the NRC (m-19)	
(T) 9-21-79	Certified copy of petition for review was mailed to the NRC & the Attorney General	
(T) 9-24-79	4—Motion of Commonwealth Edison Company, et al for leave to intervene (m-24)	
(E) 9-28-79	Clerk's order, sua sponte, that this case is consolidated with 79-2131	
(D) 10-12-79	4—Petitioner's response to NRDC, Inc., motion in 79-2131 to hold in abeyance (m-4) (OK DMC)	
(E) 10-19-79	Clerk's order granting the motion of Commonwealth Edison Company, et al. for leave to intervene	
(T) 10-19-79	4—Motion of Tennessee Valley Authority for leave to intervene (m-18)	
(D) 10-22-79	4—Motion of Baltimore Gas and Electric Co., et al., for leave to intervene (m-22)	
(D) 10-22-79	4—Motion of State of Wisconsin, for leave to intervene (m-18)	
(D) 11- 2-79	Certified Index to Record (n-9)	
(D) 11-14-79	4—Motion of Baltimore Gas & Electric Co., et al. to correct motion for leave to intervene (m-14)	
(D) 11-26-79	4—Petitioner's motion to extend time to file brief (m-26)	

DATE	FILINGS—PROCEEDINGS	Filed
(T) 11-27-79	Clerk's order: The Court request concise responses to the following questions (1-5, see order) from petitioners and intervenors within 15 days of this order; respondents and intervenors shall similarly file their responses to the questions 10 days thereafter: (1) the NRC's motion to dismiss 74-1385 and 74-1586 and (2) the NRDC's motion to establish the record in 74-1385, 74-1586 and 77-1448 are denied without prejudice; petitioners' motions to enforce the mandate and injunctive relief in 73-1776 and 73-1867 (filed March 20, 1978[)] are denied and the mandate is recalled; (1) the motions of Tennessee Valley Authority and BG&E, et al. for leave to intervene in 79-2110 and 79-2131 and (2) the motion of the State of Wisconsin for leave to intervene in 79-2110 are granted; NRC's motion for leave to file its opposition to the NRDC's request for commencement and expedited completion of review in 74-1385, 74-1586 and 77-1448 is granted; NRC's motion for an extension of time in which to reply to NRDC's motion to hold 79-2131 in abeyance is denied but treated as the NRC's response to the NRDC motion; the briefing in 79-2110 and 79-2131 is deferred until subsequent Court order; and that ruling on NRDC's motion to commence and expedite review in 74-1385, 74-1586 and 77-1448 and motion to hold in abeyance 79-2131 is deferred pending further Court order	
(T) 12-10-79	4—Petitioner's response to the Court's order of November 27, 1979 (m-7)	
(T) 12-10-79	4—Intervenor's (State of Wisconsin) response to the Court's order of November 27, 1979 (m-7)	
(D) 12-26-79	4—Respondent's response to court's order of 11-27-79 (m-26)	
(D) 12-26-79	4—Intervenor's (Tennessee Valley Authority) response to court's order of 11-27-79 (m-24)	
(D) 12-26-79	4—Intervenor's (Baltimore Gas & Elec. Co., et al.) response to court's order of 11-27-79 (m-26)	
(T) 12-28-79	4—Response of Commonwealth Edison, et al. to Court's order of 11/27/79 (m-26)	

DATE	FILINGS—PROCEEDINGS	Filed
(E) 2-11-80	Per Curiam order that Nos. 74-1586, 77-1448, 79-2110 & 79-2131 are consolidated for all purposes and the following schedule is established: 1) within 20 days from this date, the parties shall file a stipulation as to the record. The parties should at this time identify those materials as to which they cannot agree to include in the record. b) within 30 days thereafter, petitioners and intervenors shall file their brief, c) within 30 days thereafter, respondent's and intervenors briefs, d) within 14 days thereafter, petitioner's and supporting intervenors reply briefs and e) within 14 days thereafter, petitioners shall file their appendices. Petitioner's need not resubmit materials preivously filed as the appendix for No. 74-1586 and these cases will be scheduled for argument as soon as the business of the Court permits; SCJ Bazelon, CJ Edwards, USCA for 6th Cir. & Tamm, CJ	
(D) 2-19-80	9—Motion of Vermont Yankee Nuclear Power Corporation for clarification of order of 2-11-80 (m-15)	
(D) 2-27-80	Supplemental Certified Index to Record (contains an omission from previously filed Certified Index (OK GF)	
(D) 3- 3-80	9—Stipulation As to Record (n 27)	
(E) 3-12-80	Per Curiam order granting intervenor's motion for clarification of order of 2-11-80 and that order is amended to provide that the filing requirements set forth in that order have no application to No. 74-1385—NRDC, Inc., et al. v. US NRC, et al.; SCJ Bazelon, Edwards, USCA Judge for Sixth Circuit and Tamm, CJ	
(D) 3-28-80	3—Petitioner's and intervenor's (State of Wisconsin) brief and appendix (m-27)	
(D) 5- 5-80	4—Intervenor's (Tennessee Valley Authority) brief (m-2)	
(D) 5- 5-80	4—Respondents' motion for leave to file motion to extend time to file brief (m-2)	

DATE	FILINGS—PROCEEDINGS	Filed
(D) 5- 7-80	25—Intervenor's (Baltimore Gas & Elec. Co., et al.) brief (m-5)	
(D) 5-13-80	4—Intervenor's (Commonwealth Edison Co., et al.) brief (m-9)	
(C) 5-21-80	Per Curiam order granting respondent's motion for leave to file motion to extend time to file brief and granting motion to May 21, 1980; SCJ Bazelon; Edwards. US CJ for the Sixth Circuit and Tamm, CJ	
(C) 5-21-80	4—Respondent's motion to extend time to file brief—granted	
(C) 5-21-80	4—Respondent's brief (m-9)	
(T) 5-23-80	4—Petitioner's and intervenor's (State of Wisconsin) reply brief (m-22)	
(B) 6-12-80	Per Curiam order granting motion of Consolidated Edison Company of New York for leave to withdraw; and the Clerk is directed to note the docket to reflect that movant Consolidated Edison Company of New York has been authorized to withdraw from Appeal Nos. 74-1586 and 77-1448 as amicus curiae and as intervenor, respectively; SCJ Bazelon, Tamm, CJ, and Edwards, CJ, USCA for the Sixth Circuit	
(E) 6-18-80	Per Curiam order granting petitioner's motion to extend time to file supplemental joint appendix to June 25, 1980; SCJ Bazelon, Tamm, CJ and CJ Edwards, USCA for Sixth Circuit	
(B) 7-11-80	Per Curiam order granting motion to extend time and the time within which petitions may file a supplemental joint appendix is extended to 7-10-80; SCJ Bazelon, Edwards, Judge, US Court of Appeals for the Sixth Circuit, and Tamm, CJ	
(B) 7-11-80	7—Supplemental joint appendix, Vols. I thru VI (m-10)	
(D) 7-22-80	15—Petitioner's and Intervenor's (State of Wisconsin) brief (m-21)	

DATE	FILINGS—PROCEEDINGS	Filed
(D) 7-22-80	15—Petitioner's and Intervenor's (State of Wisconsin) reply brief (m-21)	
(D) 7-24-80	15—Respondent's brief (m-24)	
(C) 7-25-80	25—Intervenor's (TVA) brief (m-24)	
(T) 7-28-80	15—Intervenors' (Commonwealth Edison Company, et al) brief (m-24)	
(T) 7-28-80	25—Intervenors' (Baltimore Gas & Electric Company, et al) brief (m-25)	
(B) 8-13-80	Per Curiam order that the parties are requested to file simultaneous memoranda by noon, Sept. 5, 1980, addressing the following questions propounded by the Court. Responses should be brief and make precise citations to the administrative record where appropriate, (see order for further information); No Judges disclosed	
(T) 9- 4-80	15—Petitioners' and intervenor's (State of Wisconsin) memorandum in response to the Court's order of August 13, 1980 (m-3)	
(T) 9- 5-80	4—Intervenors' (Baltimore Gas) response to the Court's order of August 13, 1980 (m-5)	
(T) 9- 5-80	15—Intervenors' (Commonwealth Edison, et al) response to the Court's order of August 13, 1980 (m-5)	
(T) 9- 5-80	25—Intervenor's (Tennessee Valley Authority) response to the Court's order of August 13, 1980 (m-4)	
(T) 9- 5-80	4—NRC's response to the Court's order of August 13, 1980 (m-5)	
(C) 9-12-80	Clerk's order, sua sponte, that the following times are allotted for oral argument: Petitioners—45 minutes; Respondent & Intervenors—45 minutes; Counsel are directed to allocate this time among themselves. Leave is granted for more than two counsel to argue on each side	

DATE	FILINGS—PROCEEDINGS	Filed
(B) 9-17-80	Argued before SCJ Bazelon * and Wilkey, CJ, and CJ George Edwards, Jr., USCA for the Sixth Circuit	
(C) 3-13-81	4—Letter dated 3/12/81 from NRC advising of status (m-12)	
(B) 10- 7-81	Per Curiam order, sua sponte, that the Nuclear Regulatory Commission advise, as soon as possible, as to when the Commission expects to promulgate the Narrative Explanation of Table S-3; SCJ Bazelon, George C. Edwards, Chief Judge, USCA for the Sixth Circuit and Wilkey, CJ	
(V) 10-19-81	4—Letter from counsel for NRC advising of status pursuant to order of 10/07/81 (m-16)	
(S) 4-27-82	Opinion for the Court filed by SCJ Bazelon	
(S) 4-27-82	Opinion concurring in part and dissenting in part filed by CJ George Edwards	
(S) 4-27-82	Dissenting opinion filed by CJ Wilkey	
(S) 4-27-82	Judgment that the orders of the NRC under review are vacated and the cases are remanded for further proceedings consistent with the opinion for the Court	
(C) 5- 7-82	4—Intervenors' (Comm. Edison Co., et al.) motion to extend time to file petition for rehearing or suggestion for rehearing en banc (m-7)	
(V) 5-27-82	Per Curiam order that the time for filing petitions for rehearing and/or suggestions for rehearing en banc is established as 45 days from the date of judgment for all parties; SCJ Bazelon, CJ George C. Edwards, Jr., USCA for the 6th Circuit and Wilkey, CJ	
(B) 6-11-82	15—Intervenors' (Commonwealth Edison, et al.) petition for rehearing and suggestion for rehearing en banc (m-11)	
(B) 6-11-82	15—Intervenor's (Baltimore Gas) suggestion for rehearing en banc (m-11)	

DATE	FILINGS—PROCEEDINGS	Filed
(B) 6-11-82	15—Respondent's petition for rehearing and suggestion for rehearing en banc (m-11)	
(V) 6-29-82	Per Curiam order that petitioner's (NRDC, Inc.) motion to hold in abeyance and request for permission to supplement is granted; SCJ Bazelon, CJ George C. Edwards, Jr., USCA for the 6th Circuit and Wilkey, CJ	
(V) 6-30-82	Per Curiam order that the petitions for rehearing filed by respondents and by intervenors Commonwealth Edison Company, et al. and Pacific Legal Foundation are denied; SCJ Bazelon, CJ George C. Edwards, Jr., USCA for the 6th Circuit and Wilkey, CJ (Statement of SCJ Bazelon as to why he voted to deny rehearing, attached. Judge Wilkey's position is set forth in his statement attached to the en banc order entered this date)	
(V) 6-30-82	Per Curiam order, en banc, that the suggestions for rehearing en banc filed by respondents and by intervenors Commonwealth Edison Company, et al., Pacific Legal Foundation and Baltimore Gas & Electric Company, et al. are denied; CJ Robinson, SCJ Bazelon, Wright (who did not participate), CJ, CJ George C. Edwards, Jr., USCA for the 6th Circuit, Wilkey, Wald, Mikva and Ginsburg, CJs (Judge Wilkey does not ask for en banc consideration because he believes nothing should delay consideration of this case by the Supreme Court. Judge Tamm, MacKinnon, Harry T. Edwards and Bork are recused)	
(C) 7- 6-82	4—Intervenor's (BG&E) motion for stay of mandate (m-11)	
(C) 7- 7-82	4—Respondents' motion to stay issuance of mandate (m-7)	
(C) 7- 7-82	4—Intervenors' (Comm. Ed, et al.) motion for stay of mandate (m-7)	
(C) 7-13-82	9—NRDC's opposition to motions to stay issuance of mandate or motion for other appropriate relief (m-13)	
(S) 7-20-82	Orders of 6-30-82 issued in printed form	

DATE	FILINGS—PROCEEDINGS	Filed
(B) 7-19-82	4—Respondent's reply to the NRDC's opposition to the motion for stay of mandate (m-19)	
(C) 7-21-82	4—Intervenors' (BG&E, et al.) reply to NRDC's opposition to motions for stay of mandate (m-21)	
(C) 9- 1-82	Per Curiam order granting motions for stay of mandate and Clerk is directed not to issue the mandate herein for a period of 30 days from the date of this order; Bazelon, SCJ; Edwards, Chief Judge, USCA for the 6th Circuit and Wilkey, CJ	
(T) 9-28-82	Letter from Clerk, Supreme Court that petition for writ of certiorari was filed on 09-24-82 in SC No. 82-524 (Baltimore Gas and Electric Co., et al.)	
(T) 9-30-82	Notification from Clerk, Supreme Court that petition for writ of certiorari was filed on 09-28-82 in SC No. 82-551 (Commonwealth Edison Co., et al.)	
(T) 9-30-82	Notification from Clerk, Supreme Court that petition for writ of certiorari was filed on 09-27-82 in SC No. 82-545 (U.S. NRC, et al.)	
(S) 10- 6-82	Per Curiam order by the Court sua sponte that the opinion concurring in part and dissenting in part filed by Chief Judge George Edwards on 4-27-82 in this case is hereby amended (see order for details)	
(T) 11-10-82	4—Letter dated 11-08-82 from counsel for NRC enclosing (15) copies of the Statement of Policy (m-8)	
(J) 12- 2-82	Certified copy of order from Clerk, Supreme Court granting petition for writ of certiorari in SC No. 82-524 on 11-29-82 (Baltimore Gas and Electric Co., et al.)	
(J) 12- 2-82	Certified copy of order from Clerk, Supreme Court granting petition for writ of certiorari in SC No. 82-545 on 11-29-82 (U.S. NRC, et al.)	
(J) 12- 2-82	Certified copy of order from Clerk, Supreme Court granting petition for writ of certiorari in SC No. 82-551 on 11-29-82 (Commonwealth Edison Co., et al.)	

[DOCKET ENTRIES IN THE COURT BELOW
IN
DOCKET NO. 79-2131]

GENERAL DOCKET

UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

DATE	FILINGS—PROCEEDINGS	Filed
(B) 9-24-79	4—Petitioner's petition for review of an order of the Nuclear Regulatory Commission (m-24)	
(B) 9-25-79	Certified copy of petition for review was mailed to the NRC and the Attorney General	
(B) 9-24-79	4—Petitioner's (NRDC) motion to hold in abeyance (m-24)	
(D) 9-26-79	4—Motion of Commonwealth Edison Co., et al., for leave to intervene (m-26)	
(E) 9-28-79	Clerk's order, sua sponte, that this case is consolidated with 79-2110	
(D)10- 2-79	4—Respondent's (NRC) motion to extend time to reply to petitioner's motion to hold proceedings in abeyance (m-2)	
(E)10-19-79	Clerk's order granting the motion of Commonwealth Edison Company, et al. for leave to intervene.	
(T)10-19-79	4—Motion of Tennessee Valley Authority for leave to intervene (m-18)	
(D)10-22-79	4—Motion of Baltimore Gas and Electric Co., et al., for leave to intervene (m-22)	
(D)11- 2-79	Certified Index to Record (n-9)	
(D)11-14-79	4--Motion of Baltimore Gas & Electric Co., et al. to correct motion for leave to intervene (m-14)	
(D)11-26-79	4—Petitioner's motion to extend time to file brief (m-26)	

DATE	FILINGS—PROCEEDINGS	Filed
(T)11-27-79	Clerk's order: The Court request [*sic*] concise responses to questions 1-5 (see order) from petitioners and intervenors within 15 days of this order; respondents and intervenors shall similarly file their responses to the questions 10 days thereafter; (1) the NRC's motion to dismiss 74-1385 and 74-1586 and (2) the NRDC's motion to establish the record in 74-1385, 74-1586 and 77-1448 are denied with prejudice; petitioners' motions to enforce the mandate and injunctive relief in 73-1776 and 73-1867 (filed March 20, 1978) are denied and the mandate is recalled; (1) the motions of Tennessee Valley Authority and BG&E, et al for leave to intervene in 79-2110 and 79-2131 and (2) the motion of the State of Wisconsin for leave to intervene in 79-2110 are granted; NRC's motion for leave to file its opposition to the NRDC's request for commencement and expedited completion of review in 74-1385, 74-1586 and 77-1448 is granted; NRC's motion for any extension of time in which to reply to NRDC's motion to hold 79-2131 in abeyance is denied but treated as the NRC's response to the NRDC motion; the briefing in 79-2110 and 79-2131 is deferred until subsequent Court order; and that ruling on NRDC's motion to commence and expedite review in 74-1385, 74-1586 and 77-1448 and motion to hold in abeyance No. 79-2131 is deferred pending further Court order	
(D)12-12-79	9—Petitioners' response to court's order of 11-27-79 (m-27)	
(D)12-26-79	4—Respondent's response to court's order of 11-27-79 (m-26)	
(D)12-26-79	4—Intervenor's (Tennessee Valley Authority) response to court's order of 11-27-79 (m-24)	
(D)12-26-79	4—Intervenor's (Baltimore Gas & Elec. Co., et al.) response to court's order of 11-27-79 (m-26)	
(T)12-28-79	4—Response of Commonwealth Edison, et al. to court's order of 11/27/79 (m-26)	

DATE	FILINGS—PROCEEDINGS	Filed
(D) 2-11-80	Per Curiam order that Nos. 74-1586, 77-1448, 79-2110 & 79-2131 are consolidated for all purposes and the following schedule is established: a) within 20 days from the date of this order, the parties shall file a stipulation as to the record. The parties should at that time identify those materials as to which they can not agree to include in the record. b) within 30 days thereafter, petitioners and intervenors in support of petitioners shall file and serve their brief, c) within 30 days thereafter, respondent and supporting intervenor's briefs, d) within 14 days thereafter, petitioners and supporting intervenor's briefs, reply brief and e) within 14 days thereafter, petitioners shall file their appendices. Petitioners need not resubmit materials previously filed as the appendix for No. 74-1586 and these cases will be scheduled for argument as soon after that time as the business of the Court permits; SCJ Bazelon, CJ Edwards, USCA for Sixth Circuit and Tamm, CJ	
(D) 2-19-80	9—Motion of Vermont Yankee Nuclear Power Corporation for clarification of order of 2-11-80 (m-15)	
(D) 2-27-80	Supplemental Certified Index to Record (contains an omission from previously filed Certified Index (OK CF)	
(D) 3- 3-80	9—Stipulation As to Record (n-27)	
(E) 3-12-80	Per Curiam order granting intervenor's motion for clarification of order of 2-11-80 and that order is amended to provide that the filing requirements set forth in that order have no application to No. 74-1385—NRDC, Inc., et al. v. US NRC, et al., SCJ Bazelon, Edwards, USCA Judge for Sixth Circuit and Tamm, CJ	
(T) 4- 2-80	4—Petitioner's brief (m-2)	
(D) 5- 5-80	4—Intervenor's (Tennessee Valley Authority) (m-2)	
(D) 5- 5-80	4—Respondents' motion for leave to file motion to extend time to file brief (m-2)	

DATE	FILINGS—PROCEEDINGS	Filed
(D) 5- 7-80	25—Intervenor's (Baltimore Gas & Elec. Co., et al.) brief (m-5)	
(D) 5-13-80	4—Intervenor's (Commonwealth Edison Co., et al.) brief (m-9)	
(C) 5-21-80	Per Curiam order granting respondent's motion for leave to file motion to extend time to file brief and granting motion to May 21, 1980; SCJ Bazelon; Edwards, US CJ for the Sixth Circuit and Tamm, CJ	
(C) 5-21-80	4—Respondent's motion to extend time to file brief—granted	
(C) 5-21-80	4—Respondent's brief (m-9)	
(C) 5-30-80	4—Petitioner's motion to extend time to file supplemental joint appendix to 6/25/80 (m-30)	
(C) 5-30-80	4—Petitioner's reply brief (m-30)	
(B) 6-12-80	Per Curiam order granting motion of Consolidated Edison Company of New York for leave to withdraw; and the Clerk is directed to note the docket to reflect that movant Consolidated Edison Company of New York has been authorized to withdraw from Appeal Nos. 74-1586 and 77-1448 as amicus curiae and as intervenor, respectively; SCJ Bazelon, Tamm, CJ, and Edwards, CJ, USCA for the Sixth Circuit	
(E) 6-18-80	Per Curiam order granting petitioner's motion to extend time to file supplemental joint appendix to June 25, 1980; SCJ Bazelon, Tamm, CJ and Edwards, Chief Judge, USCA for Sixth Circuit	
(D) 6-25-80	4—Petitioner's motion to extend time to file supplemental joint appendix to 7-10-80 (m-25)	
(B) 7-11-80	Per Curiam order granting petitioner's motion to extend time and the time within which to file a supplemental joint appendix is extended to 7-10-80; SCJ Bazelon, Edwards, Judge, US Court of Appeals for the Sixth Circuit, and Tamm, CJ	
(B) 7-11-80	7—Petitioner's supplemental joint appendix, Vols. I thru VI (m-10)	

DATE	FILINGS—PROCEEDINGS	Filed
(D) 7-24-80	15—Petitioners' brief (m-24)	
(D) 7-24-80	15—Petitioners' reply brief (m-24)	
(D) 7-24-80	15—Respondent's brief (m-24)	
(C) 7-25-80	25—Intervenor's (TVA) brief (m-24)	
(T) 7-28-80	15—Intervenors' (Commonwealth Edison Company, et al) brief (m-24)	
(T) 7-28-80	25—Intervenors' (Baltimore Gas and Electric Company, et al) brief (m-25)	
(B) 8-13-80	Per Curiam order that the parties are requested to file simultaneous memoranda by noon, Sept. 5, 1980, addressing the following questions propounded by the Court. Responses should be brief and make precise citations to the administrative record where appropriate, (see order for further information); No Judges disclosed	
(T) 9- 5-80	4—Petitioners' response to the Court's order of August 13, 1980 (m-5)	
(T) 9- 5-80	4—NRC's response to the Court's order of August 13, 1980 (m-5)	
(T) 9- 5-80	4—Intervenors' (Baltimore Gas) response to the Court's order of August 13, 1980 (m-5)	
(T) 9- 5-80	15—Intervenors' (Commonwealth Edison, et al) response to the Court's order of August 13, 1980 (m-5)	
(T) 9- 5-80	25—Intervenor's (Tennessee Valley Authority) response to the Court's order of August 13, 1980 (m-4)	
(C) 9-12-80	Clerk's order, sua sponte, that the following times are allotted for oral argument: Petitioners—45 minutes; Respondent & Intervenors—45 minutes; Counsel are directed to allocate this time among themselves. Leave is granted for more than two counsel to argue on each side	
(B) 9-17-80	Argued before SCJ Bazelon * and Wilkey, CJ, and CJ George Edwards, Jr., USCA for the Sixth Circuit	

DATE	FILINGS—PROCEEDINGS	Filed
(C) 3-13-81	4—Letter dated 3/12/81 from NRC advising of status (m-12)	
(B) 10- 7-81	Per Curiam order, sua sponte, that the Nuclear Regulatory Commission advise, as soon as possible, as to when the Commission expects to promulgate the Narrative Explanation of Table S-3; SCJ Bazelon, George C. Edwards, Chief Judge, USCA for the Sixth Circuit and Wilkey, CJ	
(V) 10-19-81	4—Letter from counsel for NRC advising of status pursuant to order of 10/07/81 (m-16)	
(S) 4-27-82	Opinion for the Court filed by SCJ Bazelon	
(S) 4-27-82	Opinion concurring in part and dissenting in part filed by CJ George Edwards	
(S) 4-27-82	Dissenting opinion filed by CJ Wilkey	
(S) 4-27-82	Judgment that the orders of the NRC under review are vacated and the cases are remanded for further proceedings consistent with the opinion for the Court	
(C) 5- 7-82	4—Intervenors' (Comm. Edison Co., et al.) motion to extend time to file petition for rehearing or suggestion for rehearing en banc (m-7)	
(G) 5-11-82	4—Petitioner's bill of costs (m-11)	
(V) 5-27-82	Per Curiam order that the time for filing petitions for rehearing and/or suggestions for rehearing en banc is established as 45 days from the date of judgment for all parties; SCJ Bazelon, CJ George C. Edwards, Jr., USCA for the 6th Circuit and Wilkey, CJ	
(B) 5-27-82	4—Petitioner's (NRDC) motion for entry of order awarding reasonable attorney's fees (m-27)	
(B) 5-27-82	4—Petitioner's (NRDC) motion to hold in abeyance and request for permission to supplement (m-27)	
(B) 6-11-82	15—Intervenors' (Commonwealth Edison, et al.) petition for rehearing and suggestion for rehearing en banc (m-11)	

DATE	FILINGS—PROCEEDINGS	Filed
(B) 6-11-82	15—Intervenor's (Baltimore Gas) suggestion for rehearing en banc (m-11)	
(B) 6-11-82	15—Respondent's petition for rehearing and suggestion for rehearing en banc (m-11)	
(V) 6-29-82	Per Curiam order that petitioner's (NRDC, Inc.) motion to hold in abeyance and request for permission to supplement is granted; SCJ Bazelon, CJ George C. Edwards, Jr., USCA for the 6th Circuit and Wilkey, CJ	
(V) 6-30-82	Per Curiam order that the petitions for rehearing filed by respondents and by intervenors Commonwealth Edison Company, et al. and Pacific Legal Foundation are denied; SCJ Bazelon, CJ George C. Edwards, Jr., USCA for the 6th Circuit and Wilkey, CJ (Statement of SCJ Bazelon as to why he voted to deny rehearing, attached. Judge Wilkey's position is set forth in his statement attached to the en banc order entered this date)	
(V) 6-30-82	Per Curiam order, en banc, that the suggestions for rehearing en banc filed by respondents and by intervenors Commonwealth Edison Company, et al., Pacific Legal Foundation and Baltimore Gas & Electric Company, et al. are denied; CJ Robinson, SCJ Bazelon, Wright (who did not participate), CJ, CJ George C. Edwards, Jr., USCA for the 6th Circuit, Wilkey, Wald, Mikva and Ginsburg, CJs (Judge Wilkey does not ask for en banc consideration because he believes nothing should delay consideration of this case by the Supreme Court. Judges Tamm, MacKinnon, Harry T. Edwards and Bork are recused)	
(C) 7- 6-82	4—Intervenor's (BG&E) motion for stay of mandate (m-11)	
(C) 7- 7-82	4—Respondents' motion to stay issuance of mandate (m-7)	
(C) 7- 7-82	4—Intervenors' (Comm. Ed., et al.) motion for stay of mandate (m-7)	

DATE	FILINGS—PROCEEDINGS	Filed
(C) 7-13-82	9—NRDC's opposition to motions to stay issuance of mandate or motion for other appropriate relief (m-13)	
(S) 7-20-82	Orders of 6-30-82 issued in printed form	
(B) 7-19-82	4—Respondent's reply to the NRDC's opposition to the motion for stay of mandate (m-19)	
(C) 7-21-82	4—Intervenors' (BG&E, et al.) reply to NRDC's opposition to motions for stay of mandate (m-21)	
(C) 9- 1-82	Per Curiam order granting motions for stay of mandate and Clerk is directed not to issue the mandate herein for a period of 30 days from the date of this order; Bazelon, SCJ; Edwards, Chief Judge, USCA for the 6th Circuit and Wilkey, CJ	
(T) 9-28-82	Letter from Clerk, Supreme Court that petition for writ of certiorari was filed on 09-24-82 in SC No. 82-524 (Baltimore Gas and Electric Co., et al.)	
(T) 9-30-82	Notification from Clerk, Supreme Court that petition for writ of certiorari was filed on 09-28-82 in SC No. 82-551 (Commonwealth Edison Co., et al.)	
(T) 9-30-82	Notification from Clerk, Supreme Court that petition for writ of certiorari was filed on 09-27-82 in SC No. 82-545 (U.S. NRC, et al.)	
(S) 10- 6-82	Per Curiam order by the Court sua sponte that the opinion concurring in part and dissenting in part filed by Chief Judge George Edwards on 4-27-82 in this case is hereby amended (see order for details)	
(T) 11-10-82	4—Letter dated 11-08-82 from counsel for NRC enclosing (15) copies of the Statement of Policy (m-8)	
(J) 12- 2-82	Certified copy of order from Clerk, Supreme Court granting petition for writ of certiorari in SC No. 82-524 on 11-29-82 (Baltimore Gas and Electric Co., et al.)	

DATE	FILINGS—PROCEEDINGS	Filed
(J)12- 2-82	Certified copy of order from Clerk, Supreme Court granting petition for writ of certiorari in SC No. 82-545 on 11-29-82 (U.S. NRC, et al.)	
(J)12- 2-82	Certified copy of order from Clerk, Supreme Court granting petition for writ of certiorari in SC No. 82-551 on 11-29-82 (Commonwealth Edison Co., et al.)	

UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

No. 74-1586

NATURAL RESOURCES DEFENSE COUNCIL, INC., and
CONSOLIDATED NATIONAL INTERVENORS,
Petitioners,

v.

UNITED STATES ATOMIC ENERGY COMMISSION, and
UNITED STATES OF AMERICA,
Respondents.

CERTIFIED INDEX OF THE RECORD

The Atomic Energy Commission hereby certifies that the material listed and described below constitutes the administrative record underlying the Commission decision which is the subject of the instant petition for review.

By the Commission.

In witness whereof I have hereunto subscribed my name and caused the seal of the Atomic Energy Commission to be affixed this 15th day of July, 1974, at Germantown, Maryland.

/s/ Paul C. Bender
PAUL C. BENDER
Secretary of the Commission

UNITED STATES OF AMERICA
ATOMIC ENERGY COMMISSION

ENVIRONMENTAL EFFECTS OF THE URANIUM FUEL CYCLE

Docket No. RM-50-3

INDEX [*]

Date of Document	Docket Page No.	Title or Description of Document
		VOLUME 1
Nov. 10, 1972	1	Notice of Consideration of Amendment to 10 CFR Part 50, Appendix D, Relating to Nuclear Fuel Cycle, with copy of letter from Roisman (CNI/UCS) to Director of Regulation re scheduling and letter from Director of Regulation to Roisman
Nov. 30, 1972	16	Letter from Teknekron, Inc., indicating intent to participate in hearing
Dec. 8, 1972	17	Letter from H. Lowenberg, Directorate of Licensing, AEC, with noncopyrighted reference material used in connection with preparation of "Environmental Survey of the Nuclear Fuel Cycle" (Statistical Data of the Uranium Industry . . .; Waste Guide for the Uranium Milling Industry . . .; Uranium Conversion; The Growth of Nuclear Power . . .; Commercial Capability to Process; Spent Fuel Reprocessing Plant . . .; Lease Agreement, State of Nevada —Nuclear Engineering Co. . . .; Department of Transportation "Radioactive Materials and Other Miscellaneous Amendments" . . .)

[*] The column indicating the "Date Docketed Office of the Secretary" has been omitted in printing.

Date of Document	Docket Page No.	Title or Description of Document
		VOLUME 2
Dec. 14, 1972	776	Letter from Roisman (Consolidated National Intervenors) requesting "Management of Commercial High Level Wastes" with copy letter from Roisman to Director of Regulation dated Nov. 21, 1972 and letter from Director of Regulation to Roisman dated Nov. 29, 1972
Dec. 14, 1972	780	Atomic Industrial Forum letter requesting opportunity to participate in rulemaking hearing
Dec. 22, 1972	782	Sport Fishing Institute letter requesting opportunity to comment and that letter be made part of official record
Dec. 27, 1972	784	Supplemental Notice of Rule Making Hearing, with certificate of service
Dec. 29, 1972	791	Babcock & Wilcox Notice of Appearance in Rulemaking Hearing (Edgar)
Dec. 29, 1972	792	NUMEC Notice of Appearance in Rule-Making Hearing (Lewis, Edgar)
Dec. 26, 1972	793	Letter from Steve J. Gadler requesting to present views
Dec. 22, 1972	794	Letter from Crawford, Edison Electric Institute, requesting opportunity to participate in rulemaking hearing
Dec. 23, 1972	795	Letter from Dickeman, Jersey Nuclear Company, Inc., reserving opportunity to participate in hearings
Dec. 30, 1972	796	Telegram from Hunton, Williams, Gay and Gibson indicating participation on behalf of 14 utilities
Dec. 29, 1972	801	Letter from Wiesemann, Westinghouse Electric Corporation, re intention to present statement at rulemaking hearing

Date of Document	Docket Page No.	Title or Description of Document
Dec. 27, 1972	802	Letter from Levy, General Electric Company, re intent to appear at rulemaking hearing
Dec. 27, 1972	804	Letter from Arthur, Duquesne Light Company, recommending that environmental effects associated with uranium fuel cycle should not be considered in individual power reactor licensing cases
Dec. 28, 1972	806	Letter from Lutkin, Mississippi Power and Light Company, making statement re rulemaking hearing
Dec. 29, 1972	807	Letter from Landis, Gulf General Atomic Company, with attached statement commenting on proposed rulemaking
Dec. 29, 1972	810	Letter from Environmental Protection Agency re intention to present oral testimony at rulemaking hearing; with certificate of service re items pages 802-810
Dec. 15, 1972	813	Letter from Professor Ruby, University of California, Berkeley, commenting on proposed rulemaking
Dec. 28, 1972	815	Letter from H. W. Brook, Nuclear Fuel Services, Inc., re intent to appear at hearing to present views
Dec. 29, 1972	816	Letter from Dzugan, Minnesota Pollution Control Agency, re participation in rulemaking hearing
Dec. 28, 1972	817	Letter from Hoffman, Sierra Club Legal Defense Fund, Inc., re desire to present views at rulemaking hearing
Dec. 29, 1972	818	Letter from Miller (Isham, Lincoln and Beale) re Commonwealth Edison Company intent to present views at rulemaking hearing; with certificate of service re items pages 813-818

Date of Document	Docket Page No.	Title or Description of Document
Dec. 29, 1972	821	Letter from MacDonald, New York State Department of Commerce, Atomic Energy Council, re intent to present views
Dec. 29, 1972	822	Letter from Wiesemann, Westinghouse Electric Corporation, re intent to present statement, with certificate of service
Jan. 5, 1973	826	Letter from Lowenberg, Directorate of Licensing, AEC, with additional material utilized in preparation of staff report "Environmental Survey of the Nuclear Fuel Cycle" (includes internal correspondence, comments, calculations, previous draft reports, etc.) (continued in Volume 3)
		VOLUME 3
Undated	1,325	(continued from Volume 2)—additional material utilized in preparation of staff report "Environmental Survey of the Nuclear Fuel Cycle" provided by Lowenberg, AEC Directorate of Licensing
		VOLUME 4
Undated	1,967	(continued from Volume 3)—additional material utilized in preparation of staff report "Environmental Survey of the Nuclear Fuel Cycle" provided by Lowenberg, AEC Directorate of Licensing
		VOLUME 5
Undated	2,508	(continued from Volume 4)—additional material utilized in preparation of staff report "Environmental Survey of the Nuclear Fuel Cycle" provided by Lowenberg, AEC Directorate of Licensing

Date of Document	Docket Page No.	Title or Description of Document
		VOLUME 6
Undated	3,244	(continued from Volume 5)—additional material utilized in preparation of staff report "Environmental Survey of the Nuclear Fuel Cycle" provided by Lowenberg, AEC Directorate of Licensing
		VOLUME 7
Undated	3,892	(continued from Volume 6)—additional material utilized in preparation of staff report "Environmental Survey of the Nuclear Fuel Cycle" provided by Lowenberg, AEC Directorate of Licensing
		VOLUME 8
Undated	4,431	(continued from Volume 7)—additional material utilized in preparation of staff report "Environmental Survey of the Nuclear Fuel Cycle" provided by Lowenberg, AEC Directorate of Licensing
		VOLUME 9
Undated	4,889	(continued from Volume 8)—additional material utilized in preparation of staff report "Environmental Survey of the Nuclear Fuel Cycle" provided by Lowenberg, AEC Directorate of Licensing
Jan. 4, 1973	5,364	Letter from S. M. Stoller re oral presentation at rulemaking hearing with resume of Dr. Geller, and certificate of service
Jan. 10, 1973	5,369	Letter from Murray (AEC staff counsel) to Roisman (Consolidated National Intervenors) with copy of "Management of Commercial High-Level Radioactive Wastes" dated March 17, 1972

Date of Document	Docket Page No.	Title or Description of Document
Jan. 9, 1973	5,406	Letter from Roisman (Consolidated National Intervenors) with Notice of Intent to Participate (CNI and Union of Concerned Scientists) with certificate of service
Jan. 11, 1973	5,412	Telegram from Board re planning session for rulemaking hearing (scheduling, etc.) with certificate of service
		VOLUME 10
Jan. 12, 1973	5,416	Letter from Fritsch, Gulf United Nuclear Fuels Corporation, commenting on proposed rulemaking, with certificate of service
Jan. 15, 1973	5,421	Letter from Upton (LeBoeuf, Lamb . . .) with initial comments of eight utilities on proposed rulemaking
Jan. 15, 1973	5,433	Letter from Freeman (Hunton, Williams, Gay and Gibson) commenting on behalf of 14 utilities in connection with proposed rulemaking
Jan. 11, 1973	5,450	Letter from Youngdahl (Consumers Power Company) commenting on proposed rulemaking
Jan. 11, 1973	5,453	Letter from Raymond (Florida Power Corporation) with comments on proposed rulemaking
Jan. 12, 1973	5,461	Letter from Owen (Duke Power Company) commenting on proposed rulemaking
Jan. 11, 1973	5,463	Letter from Edlow (Edlow International Company) commenting on proposed rulemaking
Jan. 9, 1973	5,465	Letter from Mary E. Cohoon commenting on proposed rulemaking

Date of Document	Docket Page No.	Title or Description of Document
Jan. 12, 1973	5,466	Letter from Wiesemann (Westinghouse Electric Corporation) advising of intention to present oral statement at rulemaking hearing
Jan. 11, 1973	5,467	Letter from Hoffman (Sierra Club Legal Defense Fund, Inc.) requesting extension of time in which to file written comments
Jan. 12, 1973	5,468	Letter from Overton (American Mining Congress) commenting on proposed rulemaking
Jan. 11, 1973	5,470	Letter from Lyle (Northern Indiana Public Service Company) commenting on proposed rulemaking; with certificate of service re items pages 5,461-5,470
Jan. 11, 1973	5,476	Letter from Franklin L. Gage commenting on proposed rulemaking
Jan. 15, 1973	5,483	Letter from Watson (Tennessee Valley Authority) commenting on proposed rulemaking
Jan. 15, 1973	5,485	Letter from Johnston (Teknekron, Inc.) commenting on proposed rulemaking; with certificate of service re items pages 5,483-5,485
Jan. 18, 1973	5,491	Letter from Murray (AEC staff counsel) to Board with materials dealing with the management of radioactive wastes
Jan. 19, 1973	5,625	Further Notice of Rule Making Hearing with list of participants, with certificate of service
Jan. 15, 1973	5,636	Letter from Hunter (American Electric Power Service Corporation) commenting on proposed rulemaking
Jan. 22, 1973	5,638	Letter from Board to Natural Resources Defense Council (Lash) confirming extension of time to file comments

Date of Document	Docket Page No.	Title or Description of Document
Jan. 22, 1973	5,639	Letter from Board to Sierra Club Legal Defense Fund, Inc., confirming extension of time to file comments
Jan. 22, 1973	5,640	Letter from Board to New York State Atomic Energy Council confirming extension of time to file comments, with certificate of service re items pages 5,638-5,640
Jan. 17, 1973	5,644	Transcript of prehearing conference, Washington, D.C., pages 1-59
Jan. 18, 1973	5,705	Letter from Pedersen, New York State Department of Environmental Conservation, commenting on proposed rulemaking
Jan. 18, 1973	5,708	Letter from Long, State of Maryland Department of Natural Resources, requesting to be kept informed of proceedings, with certificate of service
Jan. 12, 1973	5,712	Letter from Kearney, Edison Electric Institute, re filing of written statement
Jan. 22, 1973	5,713	Letter from Murray (AEC staff counsel to Board with copies of correspondence and certificate of service
Jan. 18, 1973	5,721	Letter from Jones, Carolina Power and Light Company, commenting on proposed rulemaking
Jan. 18, 1973	5,723	Letter from Pedersen, State of New York Department of Environmental Conservation, commenting on proposed rulemaking, with attached comments re specific points
Jan. 19, 1973	5,733	Letter from Roisman (CNI/UCS) with list of groups participating in intervention, with certificate of service re items pages 5,721-5,733

Date of Document	Docket Page No.	Title or Description of Document
Undated	5,743	Note from King, New York State Department of Conservation, with pages 2-8 of comments on survey, with certificate of service
Jan. 22, 1973	5,754	Letter from David Reister commenting on proposed rulemaking, with certificate of service
Jan. 23, 1973	5,758	Letter from Upton (LeBoeuf, Lamb . . .) commenting on January 17, 1973 letter from Shapar (Associate General Counsel, AEC)
Jan. 29, 1973	5,760	Consolidated National Intervenors/Union of Concerned Scientists Statement with Respect to Oral Presentation with Statement of Professional Qualifications of Dr. Henry W. Kendall; Curriculum Vitae of Edward Radford, and certificate of service
Jan. 19, 1973	5,775	Letter from Environmental Protection Agency commenting on proposed rulemaking, with attached "Specific Comments . . ." and certificate of service
Jan. 24, 1973	5,789	Letter from Hoffman, Sierra Club Legal Defense Fund, Inc., with Comments of the Sierra Club on "Environmental Survey of the Nuclear Fuel Cycle"
Jan. 27, 1973	5,810	Letter from Dickeman, Exxon Nuclear Company, Inc., with Comments on Proposed Rulemaking
Jan. 29, 1973	5,814	Letter from Edgar (Babcock and Wilcox) to Board with:
Undated	5,817	Written Statement of Babcock and Wilcox
Jan. 26, 1973	5,827	Consolidated National Intervenors/Union of Concerned Scientists Notice of Schedule Rearrangement, with certificate of service

Date of Document	Docket Page No.	Title or Description of Document
Jan. 26, 1973	5,829	Letter from Restrick, General Electric Company, with Written Statement of the General Electric Company, with certificate of service
Jan. 23, 1973	5,840	Letter from Restrick, General Electric Company, requesting copies of documents be mailed to Washington, D.C. office
Jan. 29, 1973	5,841	Letter from Edgar (Babcock & Wilcox) to Board re filing of written statement
		VOLUME 11
Jan. 29, 1973	5,842	Letter from Howe, The Conservation Foundation, concurring with views of Sport Fishing Institute letter of Dec. 22, 1972, with certificate of service
Feb. 2, 1973 (sic)	5,846	Statement by Edwin A. Wiggin, Atomic Industrial Forum, with certificate of service
Undated	5,865	Statement of Dr. Frank K. Pittman, Director, Division of Waste Management and Transportation, re "Management of High-Level Wastes From a 1000 MWe Light Water Reactor", with certificate of service
Jan. 29, 1973	5,892	Testimony on Environmental Survey of the Nuclear Fuel Cycle Presented by S. H. Smiley, Deputy Director for Fuels and Materials
Feb. 1, 1973	5,913	Letter from Brollier (Hunton, Williams, Gay & Gibson) re appearance of 14 utilities at rulemaking hearing
Jan. 17, 1973	5,915	Letter from Nayfield, State of Florida Division of Health, commenting on proposed rulemaking, with certificate of service

Date of Document	Docket Page No.	Title or Description of Document
Feb. 5, 1973	5,919	Letter from Murray to Rowe (Environmental Protection Agency) re transmittal of transcript pages for clarification of testimony
Feb. 1, 1973	5,920	Transcript of hearing, Washington, D.C., pages 60-306
Feb. 2, 1973	6,217	Transcript of hearing, Washington, D.C., pages 307-520
Jan. 30, 1973	6,410	Statement of the Edison Electric Institute
Feb. 8, 1973	6,413	Letter from Upton (LeBoeuf, Lamb . . .) on behalf of eight utilities, with:
Feb. 8, 1973	6,414	Participants' Proposed Corrections to Transcript
Feb. 3, 1973	6,417	Letter from Franklin L. Gage with:
Feb. 3, 1973	6,418	Comments Concerning the Environmental Impact of the Nuclear Fuel Cycle
Feb. 2, 1973	6,421	Letter from Environmental Protection Agency responding to Board's request for clarification, with certificate of service
Feb. 13, 1973	6,426	Letter from Murray (AEC staff counsel) to Board with staff's proposed transcript corrections
Feb. 8, 1973	6,429	Letter from Edward Kaufman, State of New Mexico Environmental Improvement Agency, commenting on proposed rulemaking, with certificate of service
Feb. 13, 1973	6,433	Transcript Corrections of 14-Member Utility Group, with certificate of service
		VOLUME 12
Feb. 16, 1973	6,439	Further Notice of Hearing, with certificate of service
Feb. 8, 1973	6,445	Letter from Dorothy A. Knowles, National Energy Board, Ottawa, requesting copies of transcripts, with copy of reply

Date of Document	Docket Page No.	Title or Description of Document
Feb. 1, 1973	6,448	Statement by Steve J. Gadler
Feb. 27, 1973	6,472	Motion of Consolidated National Intervenors/Union of Concerned Scientists in Request of Schedule Rearrangement with certificate of service
Feb. 23, 1973	6,475	Letter from Environmental Protection Agency re clarification of EPA position on the rulemaking pertaining to the uranium fuel cycle
Feb. 23, 1973	6,477	Letter from Department of the Interior commenting on proposed rulemaking, with certificate of service re items pages 6,475-6,477
Mar. 2, 1973	6,486	Letter from Roisman (CNI/UCS) with:
Undated	6,487	Consolidated National Intervenors/ Union of Concerned Scientists Statement with Respect to Legal Considerations of the Proposed Regulations on the Nuclear Fuel Cycle, with certificate of service
Mar. 2, 1973	6,518	Regulatory Staff Position on CNI/USC Motion for Delay, with certificate of service
Mar. 1, 1973	6,526	Letter from Restrick to Board with Supplemental Written Statement of General Electric Company
Mar. 6, 1973	6,538	Letter from Roisman (CNI-UCS) with Errata to the Comments of CNI/UCS on the Proposed Regulations on the Nuclear Fuel Cycle Filed March 2, 1973, with certificate of service
Mar. 7, 1973	6,542	Order on Motion for Extension of Time, with certificate of service
Mar. 7, 1973	6,549	Response of 14-Member Utility Group to Motion of CNI-UCS "In Request of Schedule Rearrangement", with certificate of service

Date of Document	Docket Page No.	Title or Description of Document
Mar. 19, 1973	6,553	Letter from Roisman (CNI/UCS) with:
Undated	6,554	Supplementary Comments by the Union of Concerned Scientists on "Environmental Survey of the Nuclear Fuel Cycle", with certificate of service
Mar. 19, 1973	6,651	Letter from Murray (AEC staff counsel) to Board with Staff Summary Comments on Proceeding for Environmental Effects of the Uranium Fuel Cycle (Part I) with attachments; Rulemaking Procedures (Part II); with certificate of service
Mar. 19, 1973	6,731	Letter from Upton with Supplementary Written Statement of Alabama Power Company, et al. (14-member utility group)
Mar. 16, 1973	6,775	Reply of 14-Member Utility Group to CNI/UCS "Statement with Respect to Legal Considerations" of March 2, 1973, with certificate of service
Mar. 19, 1973	6,794	Telegram from Westinghouse Electric Corporation (Wiesemann) commenting on question raised by Board
Mar. 9, 1973	6,799	Letter from Environmental Protection Agency re position of EPA in proceeding
Mar. 19, 1973	6,801	Letter from Wiesemann (Westinghouse) commenting on question raised by Board at hearing
Mar. 22, 1973	6,804	Letter from Roisman (CNI/UCS) re position of CNI-UCS
Mar. 26, 1973	6,805	Staff Response to Board Order of March 9, 1973, with certificate of service

Date of Document	Docket Page No.	Title or Description of Document
Jan. 26, 1973	6,809	Comments of the Natural Resources Defense Council, Inc., on the Atomic Energy Commission's Environmental Survey of the Nuclear Fuel Cycle
Mar. 24, 1973	6,818	Request of 14-Member Utility Group for Time to Review and Respond to CNI/UCS "Supplementary Comments", with certificate of service
Mar. 27, 1973	6,821	Reply of 14-Member Utility Group to Letter of March 22, 1973 from Mr. Roisman Regarding the Position of CNI-UCS, with certificate of service
Mar. 26, 1973	6,824	TELEX from Restrick, General Electric Company, requesting opportunity to respond to CNI/UCS Filing of March 19, 1973
Mar. 29, 1973	6,825	Telegram from Board granting request for extension of time to review and respond to supplementary comments
		VOLUME 13
Apr. 3, 1973	6,827	Telegram from Brook, Nuclear Fuel Services, Inc., requesting an extension of time to review and respond to supplementary comments of CNI-UCS
Mar. 19, 1973	6,828	Letter from Ayres, Natural Resources Defense Council, Inc., with Comments of the Natural Resources Defense Council, Inc. dated Jan. 26, 1973, with certificate of service
Apr. 13, 1973	6,843	Response of 14-Member Utility Group to "Supplementary Comments" of CNI-UCS with certificate of service
Undated	6,869	Comments of General Electric Company on the Supplementary Comments by the Union of Concerned Scientists

Date of Document	Docket Page No.	Title or Description of Document
Undated	6,873	Minnesota Pollution Control Agency Staff Statement in Rule Making Hearing . . . by Ken Dzugan
Apr. 13, 1973	6,880	New York State Atomic Energy Council Comments on Supplementary Comments by the Union of Concerned Scientists on "Environmental Survey of the Nuclear Fuel Cycle", with certificate of service
Apr. 16, 1973	6,890	Nuclear Fuel Services, Inc. Response to Union of Concerned Scientists, with certificate of service
Jul. 6, 1973	6,898	Report to the Commission by the Nuclear Fuel Cycle Hearing Board, with attached lists
Jun. 29, 1973	6,931	Order Approving Corrections to Transcript of hearing, with certificate of service re items pages 6,898-6,931
Jul. 12, 1973	6,944	Supplemental Order Approving Corrections to Transcript of Hearing, with certificate of service
Jan. 22, 1974	6,950	Letter from Roisman (UCS) with Union of Concerned Scientists report on nuclear fuel cycle
Apr. 16, 1974	7,165	Environmental Effects of the Uranium Fuel Cycle (rule change as published in the Federal Register) with certificate of service

[Certificate of Service Omitted in Printing]

UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

No. 77-1448

NATURAL RESOURCES DEFENSE COUNCIL, INC.,
Petitioner,

v.

UNITED STATES NUCLEAR REGULATORY COMMISSION, *et al.*,
Respondents,

BALTIMORE GAS AND ELECTRIC CO., *et al.*,
Intervenors.

CERTIFIED INDEX OF THE RECORD

The Nuclear Regulatory Commission hereby certifies that the material listed and described below constitutes an index to the administrative record underlying the Commission decision which is the subject of the above petition for review.

For the Commission

/s/ Samuel J. Chilk
SAMUEL J. CHILK
Secretary of the Commission

Dated at Washington, DC,

this 13th day of November, 1979.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ENVIRONMENTAL EFFECTS OF THE URANIUM FUEL CYCLE

Docket No. RM-50-3

(Interim Fuel Cycle Rule)

INDEX [*]

Date of Document	Document No.	Title or Description of Document
		VOLUME 14A
Aug 13, 1976	1	Federal Register Notice—General Statement of Policy [41 FR 34707 published August 16, 1976]
Oct 1976	2	Impacts of Later Reversing a Decision to Adopt or Not to Adopt an Interim Rule Permitting Construction or Operation of Nuclear Power Plants
undated	3	Response to Comments on a Paper Entitled "Impacts of Later Reversing a Decision to Adopt or Not to Adopt an Interim Rule Permitting Construction or Operation of Nuclear Power Plants"
Oct 1976	4	NUREG-0116 (Supplement 1 to WASH 1248)—Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle—A Task Force Report
Nov 5, 1976	5	Federal Register Notice—Supplemental General Statement of Policy [41 FR 49898 published November 11, 1976]

[*] The column indicating the "Date Docketed Office of the Secretary" has been omitted in printing.

Date of Document	Document No.	Title or Description of Document
Mar 7, 1977	6	Federal Register Notice—Part 51 Licensing and Regulatory Policy and Procedures for Environmental Protection—Uranium Fuel Cycle Impacts From Spent Fuel Reprocessing and Radioactive Waste Management [42 FR 13802 published March 14, 1977]
Mar 1977	7	NUREG-2016 (Supplement 2 to WASH-1248 Public Comments and Task Force Responses Regarding the Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle (NUREG-0116)
Mar 2, 1977	8	SECY-77-85A—Staff Response to Comments on a Paper Entitled "Impacts of Later Reversing a Decision to Adopt or Not to Adopt an Interim Rule Permitting Construction or Operation of Nuclear Power Plants"
May 12, 1977	9	Memorandum for Record from Chilk regarding SECY-77-85A
		VOLUME 14B
Aug 1976	1	NUREG-0002, ES—Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors
Aug 1976	2	NUREG-0002, Vol. 1—Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors—Summary
Aug 1976	3	NUREG-0002, Vol. 2—Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors

Date of Document	Document No.	Title or Description of Document
Aug 1976	4	NUREG-0002, Vol. 3—Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors
Aug 1976	5	NUREG-0002, Vol. 4—Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors
Aug 1976	6	NUREG-0002, Vol. 5—Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors

UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

No. 79-2110

THE STATE OF NEW YORK,
Petitioner,
v.
THE NUCLEAR REGULATORY COMMISSION and
THE UNITED STATES OF AMERICA, *et al.*,
Respondents.

No. 79-2131

NATURAL RESOURCES DEFENSE COUNCIL, INC.
v.
UNITED STATES NUCLEAR REGULATORY COMMISSION and
UNITED STATES OF AMERICA,
Respondents.

CERTIFIED INDEX OF THE RECORD

The Nuclear Regulatory Commission hereby certifies that the material listed and described below constitutes an index to the administrative record underlying the Commission decision which is the subject of these petitions for review.

For the Commission

/s/ Samuel J. Chilk
SAMUEL J. CHILK
Secretary of the Commission

Dated at Washington, DC,

this 29th day of October, 1979.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ENVIRONMENTAL EFFECTS OF THE URANIUM FUEL CYCLE

Docket No. RM 50-3

INDEX [*]

Date of Document	Document No.	Title or Description of Document
		VOLUME 15 [1]
May 20, 1977	1	Notice of Reopened Hearing (10 pages) with certificate of service
May 28, 1977	2	Letter Chauncey Kepford requesting to be a full participant—Environmental Coalition or Nuclear Power (1 page) with certificate of service
Jun 6, 1977	3	Letter Helene Linker (Natural Resources Defense Council) enclosing a Petition of the NRDC, Inc., for Reconsideration of the NRC's Ruling Reopening the Hearings on the Environmental Effects of the Uranium Fuel Cycle (50 pages) with certificate of service
Jun 16, 1977	4	Letter Bennett Boskey informing of intent to submit views at hearing on behalf of Allied General Nuclear Services (1 page)
Jun 9, 1977	5	Letter Ellis Cox (Atomic Industrial Forum) requesting to participate in hearings (1 page)

[*] The column indicating the "Date Docketed Office of the Secretary" has been omitted in printing.

[1] Earlier volumes not relevant to this matter.

Date of Document	Document No.	Title or Description of Document
Jun 14, 1977	6	Letter Lewis Lefkowitz (State of New York) requesting to participate in hearings (1 page) with certificate of service
Jun 15, 1977	7	Letter NRDC informing of intent to participate in hearings (2 pages)
Jun 16, 1977	8	Letter Dr. Monica Bainter informing that she will not be able to attend hearings but would like to have some input (1 page) certificate of service
undated	9	Letter Marvin J. Lewis (Environmental Coalition on Nuclear Power) requesting to testify at reopened hearings and requesting that Marvin Lewis, Judith Johnsrud, and George Boomsma be added to service list (1 page) with certificate of service
Jun 15, 1977	10	Notice of Participation—California Energy Resources Conservation and Development Commission—Laurence Lanpher (2 pages)
Jun 22, 1977	11	Letter Austin Olney (State of Delaware) requesting to participate in hearings (1 page)
Jun 22, 1977	12	Notice of Intent to Participate as a Full Party (Union of Concerned Scientists—George C. Deptula) (2 pages)
Jun 24, 1977	13	Letter C. Eicheldinger (Westinghouse) requesting to participate in hearings (1 page)
Jun 27, 1977	14	Letter Leonard Trosten (LeBeouf, Lamb, Leiby and MacRae) requesting to participate for utilities (1 page) with certificate of service
Jun 21, 1977	15	Letter Colleen Nissl (State of Ohio) requesting to participate in hearings (1 page)

Date of Document	Document No.	Title or Description of Document
Jun 23, 1977	16	Letter J. E. Gilleland (Tennessee Valley Authority) requesting to participate in hearings (1 page)
Jun 23, 1977	17	Letter John Kofron (State of Wisconsin) requesting to participate in hearings (1 page)
Jun 24, 1977	18	Letter Lawrence Jones (Pacific Legal Foundation) requesting to participate in hearings (1 page)
Jun 24, 1977	19	Environmentalists Inc.'s Intention to Present Views at the Public Hearing on Environmental Impacts of Fuel Reprocessing and Waste Management
Jun 27, 1977	20	Letter George Freeman (Hunton and Williams) on behalf of utilities requesting to participate (4 pages)
Jun 27, 1977	21	Letter J. Murray and J. Lieberman (NRC Staff) expressing plans to participate in hearings (1 page) with certificate of service
Jun 28, 1977	22	Letter Marvin Resnikoff requesting to participate in hearings (1 page)
undated	23	Letter Richard Jones (Carolina Power and Light Company) expressing intent to file written comments with certificate of service (1 page)
Jul 13, 1977	24	Notice of Prehearing Conference (2 pages) with certificate of service
Jul 19, 1977	25	Staff Motion to Establish Detailed Hearing Procedures Prior to the Start of the Continuation of the Rulemaking Hearing with attachments (9 pages) with cetrificate of service
Jul 19, 1977	26	Letter NRDC to Hearing Board requesting that the hearing be deferred (3 pages)

Date of Document	Document No.	Title or Description of Document
Jul 26, 1977	27	Hearing Board Memorandum and Order (1 page) with certificate of service
Jul 25, 1977	28	Letter NRDC enclosing Opposition to the Staff Motion to Establish Detailed Hearing Procedures Prior to the Start of the Continuation of the Rulemaking Hearings (19 pages) with certificate of service
Jul 27, 1977	29	California Energy Commission Comments on Staff Motion to Establish Detailed Procedures Prior to the Start of the Continuation of the Rulemaking (7 pages) with certificate of service
Jul 27, 1977	30	Notice of Appearance—Kathryn B. Dickson (1 page) with certificate of service
Jul 26, 1977	31	Letter Gregory A. Thomas (Sierra Club) enclosing Petition by Sierra Club to be Admitted as a Participant (2 pages) with certificate of service
Jul 28, 1977	32	TRANSCRIPT of Prehearing Conference, Bethesda, Maryland, pages 1-55
Jul 23, 1977	33	Letter Edward Marwick, requesting to participate with attachment (9 pages) with certificate of service
Jul 26, 1977	34	Letter W. D. Rowe (EPA) stating that EPA intends to present views at hearing (1 page) with certificate of service
Aug 3, 1977	35	Comments of the Union of Concerned Scientists on the Proposed Hearing Schedule and Procedures (12 pages)
Aug 3, 1977	36	Notice of Change of Address of Counsel —George C. Deptula (USC) (1 page) with certificate of service
Aug 4, 1977	37	California Energy Commission Comments Regarding the Hearing Board's Proposed Rehearing Schedule (6 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Aug 2, 1977	38	The State of Ohio's Statement in Opposition to Portions of the Staff Motion to Establish Detailed Hearing Procedures Prior to the Start of the Continuation of the Rulemaking Hearings (9 pages) with certificate of service
Aug 2, 1977	39	Letter David Powell (TVA) enclosing Comments of TVA Regarding Proposed Schedule (3 pages) with certificate of service
Aug 4, 1977	40	Comments of Commonwealth Edison, Et Al, on Proposed Board Order to Determine Format and Schedule for the Rulemaking (9 pages) with certificate of service
Aug 2, 1977	41	Letter Barton Cowan (On behalf of Westinghouse) commenting on proposed schedule (3 pages) with certificate of service
Aug 1, 1977	42	Letter Patrick Walsh enclosing State of Wisconsin's Memorandum in Response to the Board's Proposed Hearing Procedures (7 pages)
Aug 4, 1977	43	Comments of Baltimore Gas and Electric Company, Et Al. Following Prehearing Conference with attachment (11 pages) with certificate of service
Aug 2, 1977	44	Response of the State of New York to Staff Motion to Establish Detailed Hearing Procedures and to the Hearing Board's Tentative Hearing Schedule (10 pages) with certificate of service
Aug 5, 1977	45	Staff Response to Petition by Sierra Club to be Admitted as a Participant (2 pages) with certificate of service
Aug 8, 1977	46	Staff Response to Request of USEPA and E. F. Marwick to Participate (2 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Aug 5, 1977	47	The NRDC's Motion to Invite Independent Agency Participation in the Reopened Rulemaking Proceeding (3 pages) with certificate of service
Aug 8, 1977	48	Notice of Withdrawal of Appearance—Patrick Walsh to be substituted for John Kofron (1 page) with certificate of service
Aug 12, 1977	49	Hearing Board Prehearing Conference Order with appendices (12 pages)
Aug 12, 1977	50	Hearing Board Memorandum (3 pages) with certificate of service
Aug 12, 1977	51	Letter George Boomsa withdrawing from proceeding (1 page) with certificate of service
Aug 16, 1977	52	Staff Response to NRDC's Motion to Invite Independent Agency Participation in the Reopened Rulemaking Proceeding (2 pages) with certificate of service
Aug 16, 1977	53	California Energy Commission Motion for Reconsideration (4 pages) with certificate of service
Aug 19, 1977	54	State of Wisconsin's Motion for Reconsideration (4 pages) with certificate of service
Aug 22, 1977	55	Staff Response to California Energy Commission's Motion for Reconsideration of the Prehearing Conference Order (2 pages) with certificate of service
Aug 22, 1977	56	State of Ohio's Motion for Reconsideration (2 pages) with certificate of service
Sep 1, 1977	57	Staff Witnesses (5 pages) with certificate of service
Sep 1, 1977	58	Staff Response to State of Wisconsin's and Ohio's Motion for Reconsideration (2 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Sep 12, 1977	59	Hearing Board Memorandum and Order (4 pages) with certificate of service
Sep 9, 1977	60	Letter NRDC to Commissioners regarding procedural problems developing in matter (3 pages) with certificate of service
Sep 14, 1977	61	Letter George Freeman enclosing Comments of Baltimore Gas and Electric Company, et al. Following Prehearing Conference (12 pages) with certificate of service
Sep 26, 1977	62	Letter Samuel Chilk to Chauncey Kepford responding to May 28, 1977 letter requesting assistance of a procedural nature for the reopened hearing (1 page)
Sep 26, 1977	63	Letter Samuel Chilk to Marvin Resnikoff responding to June 28, 1977 letter regarding procedures and participation (1 page)
Sep 26, 1977	64	Letter Samuel Chilk to Helen [*sic*] Linker regarding petition filed June 13, 1979 requesting Commission reconsider its decision of May 24, 1977 regarding scope and procedures for hearing (3 pages) with certificate of service
Sep 27, 1977	65	Letter Romayne Skrutski (Secretary to the Hearing Board) to Marvin Lewis regarding request for copy of NUREG-0216 (1 page)
Sep 27, 1977	66	Letter Skrutski to James Murray (Staff) with letter from Marvin Lewis requesting copy of NUREG-0216 (2 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
		VOLUME 16
Oct 3, 1977	1	Statement of Robert N. Anderson on Behalf of the California Energy Resources Conservation and Development Commission (38 pages) with certificate of service
Oct 3, 1977	2	List of Witnesses and Written Statement of Pacific Legal Foundation with attachments (117 pages) and with certificate of service
Sep 28, 1977	3	Letter Cox regarding AIF Comments (1 page)
Oct 3, 1977	4	Letter LeBoeuf, Lamb, Leiby and MacRae regarding additional comments (2 pages)
Oct 3, 1977	5	Letter LeBoeuf, Lamb, Leiby and MacRae requesting that appearances of the firm be withdrawn on behalf of Consolidated Edison Company of New York, Inc. (2 pages) with certificate of service
Oct 2, 1977	6	Statement of Marvin I. Lewis (3 pages)
Oct 3, 1977	7	Letter Department of Interior with Statement of George D. DeBuchananne (3 pages)
Oct 3, 1977	8	Letter George Freeman (Hunton and Williams) to Hearing Board commenting of statement to be submitted by Baltimore Gas and Electric Company, et al. (3 pages)
Oct 3, 1977	9	Letter Barton Cowan to Hearing Board informing that Westinghouse would not be filing a statement (2 pages) with certificate of service
Sep 30, 1977	10	Statement of Peter N. Skinner on behalf of the State of New York (41 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Oct 3, 1977	11	Staff Statements (7 pages) with certificate of service
Oct 3, 1977	12	Testimony of Dr. John E. Kelly on Behalf of the States of Wisconsin and Ohio (26 pages)
Oct 3, 1977	13	Testimony of David A. Deese on behalf of the States of Wisconsin and Ohio (26 pages) with certificate of service
Oct 3, 1977	14	Initial Written Statement of Baltimore Gas and Electric Company, et al., Commonwealth Edison Company, et al., and TVA (301 pages) with certificate of service
Oct 3, 1977	15	Statement of Robert N. Anderson on behalf of the California Energy Resources Conservation and Development Commission (38 pages) with certificate of service
		VOLUME 17
Oct 3, 1977	1	Letter Helene Linker (NRDC) enclosing Statement of Arthur R. Tamplin and Thomas B. Cochran (123 pages); Statement of Terry R. Lash (67 pages); Statement of Todd R. LaPorte (19 pages); Statement of John W. Gofman (69 pages) with certificate of service
Oct 3, 1977	2	Letter Dida McMurray (Environmentalists Inc.) enclosing testimonies of Ruth Thomas, D. H. Martin and Ronald Wilder (8 pages) with certificate of service
Oct 3, 1977	3	Testimony of Dr. John E. Kelley on Behalf of the States of Wisconsin and Ohio (28 pages)

Date of Document	Document No.	Title or Description of Document
undated	4	Testimony of Dr. Irvin C. Bupp on Behalf of the States of Wisconsin and Ohio with exhibits (14 pages) with certificate of service
Oct 3, 1977	5	Statement of the Union of Concerned Scientists (5 pages)
Oct 3, 1977	6	Notice of Appearance—David Jhirad (UCS) with certificate of service
Sep 28, 1977	7	Letter Ellis Cox (AIF) submitting comments (1 page) with certificate of service
Oct 6, 1977	8	Letter Hunton and Williams requesting change in service list
Oct 6, 1977	9	Notice of Appearances—George C. Freeman, Jr., Donald P. Irwin, Michael B. Barr, and W. Stevenson Hopson, IV (Carolina Power and Light Company) (2 pages) with certificate of service
Oct 6, 1977	10	Letter Patrick Walsh (State of Wisconsin) requesting that the Commission revise schedule of presentation (2 pages)
Oct 9, 1977	11	Letter Harry Otto (State of Delaware) enclosing Statement on Behalf of the Department of Natural Resources and Environmental Control (5 pages) with certificate of service
Oct 3, 1977	12	Letter John F. Ahearne (Department of Energy) requesting that a representative be a limited participant (1 page) with certificate of service
Oct 18, 1977	13	Request of State of Delaware to Allow Late Filing of Statement (1 page) with certificate of service (Staff's Response)
Oct 17, 1977	14	Letter Dida McMurray (Environmentalists Inc.) enclosing Proposed Questions (4 pages)

Date of Document	Document No.	Title or Description of Document
Oct 18, 1977	15	Letter Helene Linker and Roger Beers (NRDC) requesting that scope of proceedings be modified (1 page) with certificate of service
Oct 20, 1977	16	Letter Herbert Sanger (TVA) regarding hearing schedule (2 pages) with certificate of service
Oct 26, 1977	17	Letter Coleen Nissl (State of Ohio) regarding procedural problems (2 pages) with certificate of service
Oct 17, 1977	18	Letter John Shea, III (State of New York) enclosing Testimony of Dr. Barry J. Smernoff (84 pages)
Oct 26, 1977	19	Errata to Statement of Peter N. Skinner on Behalf of State of New York (2 pages) with certificate of service
Oct 31, 1977	20	California Energy Resources Conservation and Development Commission's Interrogatories to Table S-3 Participants (69 pages) with certificate of service
Oct 31, 1977	21	First Round of Suggested Staff Questions and Comments on Scope of Proceeding (109 pages) with certificate of service
Oct 31, 1977	22	Questions Proposed by Commonwealth Edison Company, Et Al., for Participants in the Rulemaking (33 pages) with certificate of service
Oct 31, 1977	23	Pacific Legal Foundation Proposed Questions (36 pages) with certificate of service
Oct 31, 1977	24	Questions Proposed by the Tennessee Valley Authority (2 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Oct 31, 1977	25	Letter Barton Cowan enclosing Proposed Questions on Testimony of Arthur R. Tamplin and Thomas B. Cochran Submitted on Behalf of NRDC filed by Westinghouse (9 pages) with certificate of service
Oct 31, 1977	26	Letter George Freeman enclosing Questions of Baltimore Gas and Electric Company, Et Al. to other Participants (34 pages) with certificate of service
		VOLUME 18
Oct 31, 1977	1	Marvin I. Lewis's Questions and Requests (6 pages)
Oct 31, 1977	2	Letter Henry Coulter (Geological Survey —Department of Interior) regarding testimony submitted October 3, 1977 (1 page) with certificate of service
undated	3	State of Wisconsin's Proposed Qustions to Joseph Lieberman, Walton A. Rodger, William W. Lowe, and Thomas E. Potter, Witnesses on Behalf of Baltimore Gas and Electric Co., et al., Commonwealth Edison Company, et al., and the TVA (13 pages)
undated	4	Table S-3 Proceeding State of Wisconsin's Questions to Marc W. Goldsmith, Witness on Behalf of the Pacific Legal Foundation (2 pages) with certificate of service
Oct 31, 1977	5	Letter Harry Otto (State of Delaware) submitting list of questions for the State of Delaware (2 pages) with certificate of service
undated	6	States of Ohio, Wisconsin and New York's Questions to be Propounded to the NRC Staff at the Rulemaking Hearing (17 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Nov 3, 1977	7	Letter Samuel Chilk to Colleen K. Nissl, Esq. (State of Ohio) regarding letter of October 26, 1977 supporting requests for revisions in the schedule and order of presentation in proceeding (1 page)
Oct 28, 1977	8	Letter Samuel Chilk to Patrick Walsh, Esq. (State of Wisconsin) regarding letter of October 6, 1977 supporting requests for revisions in the schedule and order of presentation in proceeding (1 page)
Oct 28, 1977	9	Letter Samuel J. Chilk to Helene Linker, Esq. (NRDC) denying request for revisions in the schedule and order of presentation in proceeding (2 pages) with certificate of service
Nov 4, 1977	10	Staff Transmittal of EPA Statement (2 pages) with certificate of service
Sep 30, 1977	11	Letter W. D. Rowe (EPA) responding to the NRC Task Force Report Public Comments and Task Force Responses Regarding the Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle (11 pages)
Nov 10, 1977	12	Response of the California Energy Resources Conservation and Development Commission to the NRC Staff's Comments on Scope of Proceeding (5 pages) with certificate of service
Nov 11, 1977	13	Objections of Baltimore Gas and Electric Company, Et Al. to Other Participants' Proposed Questions (13 pages) with certificate of service
Nov 10, 1977	14	Staff Objections to First Round Questions (1 page) with certificate of service
Nov 10, 1977	15	Objections to Proposed Questions (Pacific Legal Foundation) (3 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
undated	16	Objections to First Round Questions by Commonwealth Edison, Et Al. (6 pages) with certificate of service
Nov 11, 1977	17	Initial Objections to Questions Suggested to the Hearing Board for Propounding to the Natural Resources Defense Council, Inc. (7 pages) with certificate of service
Nov 18, 1977	18	Hearing Board Order (2 pages)
Nov 18, 1977	19	Hearing Board Memorandum and Order (5 pages) with certificate of service
Oct 1976	20	NUREG-0116 (Supp. 1 to WASH-1248) Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle—A Task Force Report (300 pages)
Mar 1977	21	NUREG-0216 (Supp. 2 to WASH-1248) Public Comments and Task Force Responses Regarding the Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle (409 pages)
Nov 17, 1977	22	Response of the Natural Resources Defense Council to the NRC Staff's Comments on the Scope of the Proceedings (9 pages) with certificate of service
undated	23	Correction of Questions by Commonwealth Edison, Et Al. (1 page) with certificate of service
Nov 18, 1977	24	Proposed Questions to the Hearing Board to Propound to the Environmental Protection Agency (NRDC) (4 pages)
Nov 18, 1977	25	Additional Objections to Questions Suggested to the Hearing Board for Propounding to the NRDC (4 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Nov 28, 1977	26	Letter Bennett Boskey to Hearing Board regarding submissions by other participants (2 pages) with certificate of service
Nov 23, 1977	27	Opposition of Baltimore Gas and Electric Company, Et Al. to NRDC's "Additional Objections" (5 pages) with certificate of service
Nov 28, 1977	28	Hearing Board Memorandum and Order (2 pages) with certificate of service
Oct 13, 1977	29	Letter Robert Ryan (State Programs—NRDC) to Senator Alfred E. Alquist (State of California) submitting review of interim reports by California Energy Resources Conservation and Development Commission on Nuclear Fuel Reprocessing and High Level Waste Disposal (14 pages)
		VOLUME 19
Dec 1, 1977	1	Hearing Board Order (2 pages) with certificate of service
Dec 2, 1977	2	California Energy Resources Conservation and Development Commission's Responses to Questions Posed by Participants (22 pages) with certificate of service
Nov 30, 1977	3	The Natural Resources Defense Council's Motion for Extension of Time (1 page) with certificate of service
Dec 2, 1977	4	Responses to Questions Asked of Ruth Thomas by Commonwealth Edison Company, Detroit Edison, Exxon Nuclear Company, Niagara Mohawk Power Corporation, Omaha Public Power Authority of the State of New York, Public Service Company of Indiana, Inc. and Rochester Gas and Electric Company (3 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Oct 3, 1977	5	Responses to Questions Regarding Testimony of Dr. John E. Kelly (13 pages)
Nov 30, 1977	6	Responses by David A. Deese on behalf of the States of Wisconsin and Ohio to Questions from the NRC, the Pacific Legal Foundation, and Baltimore Gas and Electric Company, et al. (13 pages) with certificate of service
undated	7	Supplement and Update of Initial Testimony for the Instant Proceedings (Marvin J. Lewis) (3 pages)
Dec 2, 1977	8	Staff Response to First Round Questions (537 pages) with certificate of service
		VOLUME 20
Dec 2, 1977	1	Joint Responses of Tennessee Valley Authority, Commonwealth Edison, Et Al, and Baltimore Gas and Electric Company, Et Al. to First Round Questions on Their Joint Initial Written Statement (179 pages) with certificate of service
Nov 29, 1977	2	State of Wisconsin's Objection to Board's Order of November 18, 1977, and Request for Clarification of Board's Position on Scope of Oral Testimony (4 pages) with certificate of service
undated	3	Response of the State of New York to the NRC Staff's Comments on Scope of Proceedings (3 pages)
Dec 2, 1977	4	Answers of Peter N. Skinner to Suggested Questions of Full Participants on Behalf of the State of New York (32 pages) with certificate of service
Dec 2, 1977	5	Motion for Leave to File Written Responses Late (Pacific Legal Foundation) (2 pages)

Date of Document	Document No.	Title or Description of Document
Dec 2, 1977	6	Partial Written Response to Questions Addressed to Witnesses (7 pages) with certificate of service
Dec 2, 1977	8	Answers to Questions Propounded to Dr. Todd R. LaPorte and Dr. John W. Gofman (25 pages) with certificate of service
Dec 2, 1977	7	Sierra Club Response to Questions (91 pages) with certificate of service
Dec 5, 1977	9	Written Response to Questions Addressed to Bernard L. Cohen By the Staff and California Energy Resources Conservation and Development Commission (33 pages) with certificate of service
Dec 5, 1977	10	Answers to Questions Proposed to NRDC Not Previously Answered (13 pages)
Dec 5, 1977	11	Answers to Questions Posed in Above Entitled Action (8 pages) with certificate of service
Dec 9, 1977	12	Response to Questions Submitted by the Participant NRDC for the U. S. Geological Survey (12 pages) with certificate of service
Dec 12, 1977	13	Memorandum Chase Stephens to Participants enclosing copy of inventory sheets denoting documents available in the Docketing and Service Branch and in the Public Document Room (14 pages) with certificate of service
Dec 12, 1977	14	Staff Response to Pacific Legal Foundation's Motion for Leave to File Written Responses Late (1 page) with certificate of service

Date of Document	Document No.	Title or Description of Document
		VOLUME 21
Dec 9, 1977	1	Letter Richard Berger (State of New York) enclosing Testimony Before the Environment, Energy and Natural Resources Subcommittee on Government Operations Regarding the Impact of Nuclear Waste Management on States by Peter N. Skinner of the New York State Department of Law (29 pages)
Dec 14, 1977	2	Hearing Board Order (2 pages)
Dec 16, 1977	3	Memorandum Samuel Chilk to Hearing Board and Chase Stephens regarding procedural assistance to participants in proceeding (1 page) with certificate of service
Dec 15, 1977	4	Notice of Appearance—Karen D. Cyr (Staff) (1 page) with certificate of service
Dec. 16, 1977	5	Letter James McGranery to Hearing Board regarding service of documents (2 pages)
undated	6	Follow-up Questions Proposed by Commonwealth Edison Company, Et Al., For Participants in the Rulemaking (7 pages) with certificate of service
Dec 16, 1977	7	Sierra Club Questions Set No. 2 (9 pages) with certificate of service
Dec 16, 1977	8	Staff Suggested Follow-Up Questions (26 pages) with certificate of service
Dec 16, 1977	9	Response of Westinghouse Electric Corporation to Natural Resources Defense Council, Inc. Request for Reference to Frigerio and Stowe Report (2 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Dec 16, 1977	10	Response of the NRDC to the NRC Staff's Comments of the Relevancy of Questions (3 pages)
Dec 16, 1977	11	Proposed Follow-Up Questions to the Hearing Board to Propound to the United States Geological Survey (3 pages) with certificate of service
Dec 16, 1977	12	Proposed Follow-Up Questions to the Hearing Board to Propound to the NRC Staff (6 pages)
Dec 16, 1977	13	The NRDC's Motion to Submit Follow-Up Questions to the Environmental Protection Agency (2 pages) with certificate of service
Dec 19, 1977	14	Addendum to Staff Response to First Round of Questions (2 pages) with certificate of service
[illegible]c 16, 1977	15	Letter Kathryn B. Dickson enclosing California Energy Commission's Follow-Up Questions to the NRC (28 pages) with certificate of service
Dec 19, 1977	16	Baltimore Gas and Electric Company, Et Al. Follow-Up Questions and Motion to File Follow-Up Questions Out of Time (19 pages) with certificate of service
Dec 19, 1977	17	Amended Motion for Leave to File Writen Responses Late (1 page) with certificate of service
Dec 21, 1977	18	Letter James McGranery to Hearing Board regarding witnesses with attachments (5 pages) and with certificate of service
Dec 27, 1977	19	Response to Follow-Up Questions Submitted December 16, 1977 by the Participant NRDC for the U. S. Geological Survey (5 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
undated	20	Sierra Club Objections to Questions Posed by Commonwealth Edison, Et Al. (2 pages) with certificate of service
Dec 27, 1977	21	Letter Gregory Thomas (Sierra Club) to Hearing Board regarding service of documents (2 pages) with certificate of service
undated	22	Hearing Board Order (2 pages) with certificate of service
Dec 30, 1977	23	Letter John Shea (NY) to James McGranery regarding service list enclosing copy of Answer of Peter N. Skinner on Behalf of the State of New York to Follow Up Questions of Full Participants (6 pages) with certificate of service
Jan 4, 1977	24	Hearing Board Memorandum and Order (6 pages) with certificate of service
Nov 1, 1977	25	Sierra Club Questions Set No. 1 (11 pages) with certificate of service
Dec 30, 1977	26	The NRDC's Clarification of Late Filing of Responses to Questions (2 pages)
Dec 30, 1977	27	Answers to Questions Propounding to Terry R. Lash by the Pacific Legal Foundation (10 pages)
Dec 30, 1977	28	Motion of the NRDC for Specification of Hearing Procedures (3 pages) with certificate of service
Oct 31, 1977	29	Proposed Questions to the Hearing Board to Propound to the U. S. Geological Survey, Department of Interior (7 pages)
Oct 31, 1977	30	Proposed Questions to the Hearing Board to Propound to Baltimore Gas and Electric Company, et al. (11 pages)
Oct 31, 1977	31	Proposed Questions to the Hearing Board to Propound to the NRC Staff (116 pages)

Date of Document	Document No.	Title or Description of Document
Jan 4, 1978	32	Staff Preliminary Response to Memorandum and Order Dated December 23, 1977 Relating to Economic Matters (2 pages) with certificate of service
Jan 5, 1978	33	Response to Submission of the California Energy Resources Conservation and Development Commission Regarding Scope of S-3 Proceeding Following Termination of GESMO (2 pages) with certificate of service
Jan 3, 1978	34	Motion by the States of New York, Wisconsin and Ohio for Clarification of Board Order and/or Certification of Certain Issues to the Commission (13 pages) with certificate of service
Jan 6, 1978	35	Hearing Board Memorandum (2 pages) with certificate of service
Jan 5, 1978	36	Letter Colleen Nissl to Hearing Board informing that rescheduled hearing date causes problems (2 pages) with certificate of service
Jan 4, 1978	37	Motion by the State of Wisconsin for Clarification of the Board's Order of December 23, 1977 and/or Certification of Issue of Questions to the Commission (2 pages) with certificate of service
Dec 29, 1977	38	Letter Judith Johnsrud to Hearing Board requesting transcripts (1 page)
Jan 6, 1978	39	Letter Bennett Boskey requesting transcripts (1 page)
Jan 10, 1978	40	Letter Dr. John Buck (Hearing Board) to James Murray (NRC Staff) requesting staff to provide copies of certain items to Board and parties on the opening day of the hearing (1 page)
Jan 10, 1978	41	Hearing Board Order (1 page) with certificate of service

Date of Document	Document No.	Title or Description of Document
Jan 6, 1978	42	Letter E. Gordon (AIF) to Hearing Board informing of intention not to present an oral statement (1 page)
undated	43	Letter Marvin Lewis with statement for hearing and requesting copies of transcript (3 pages) with certificate of service
Jan 10, 1978	44	Letter Donald Irwin (Hunton and Williams) regarding scope of proceeding (5 pages) with certificate of service
Jan 12, 1979	45	Revised Staff Witness List (65 pages) with certificate of service
Jan 5, 1978	46	Letter Helene Linker (NRDC) regarding scope and suspension of hearing (3 pages)
Jan 6, 1978	47	Responses by David A. Deese on behalf of the States of Wisconsin and Ohio to Follow-Up Questions from Baltimore Gas and Electric Company, et al. and the NRC (5 pages) with certificate of service
Jan 6, 1979	48	Responses to Follow-Up Questions Regarding Testimony of Dr. John E. Kelly on Behalf of the States of Wisconsin and Ohio (14 pages) with certificate of service
Jan 12, 1978	49	Status of Staff's Economic Effort (1 page) with certificate of service
Jan 10, 1978	50	Letter Herbert Sanger (TVA) regarding scope of rulemaking (2 pages) with certificate of service
Jan 10, 1978	51	Letter P. Walsh and C. Nissl (States of Wisconsin and Ohio) regarding schedule of witnesses (2 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
undated	52	Motion for Reconsideration of Memorandum and Order of December 23, 1977 (Commonwealth Edison Company, et al.) (4 pages)
Jan 12, 1978	53	Commonwealth Edison Company, et al., Motion for Refinement of Oral Hearing Schedule (3 pages)
Jan 12, 1978	54	Letter James McGranery (Commonwealth Edison, et al.) opposing any change in scope of hearing (3 pages)
Jan 12, 1978	55	Letter James McGranery requesting copies of transcripts (1 page)
Jan 12, 1978	56	Letter McGranery regarding witnesses (5 pages) with certificate of service
Dec 27, 1977	57	Written Response to Questions Addressed to Marc W. Goldsmith (Pacific Legal Foundation) (12 pages) with certificate of service
Dec 28, 1977	58	Letter Lawrence Lanpher requesting clarification of scope of proceeding (2 pages)
Dec 23, 1977	59	Hearing Board Memorandum and Order (3 pages) with certificate of service
Dec 20, 1977	60	Letter Helene M. Linker (NRDC) to James McGranery regarding omission from service list (1 page) with certificate of service
Dec 23, 1977	61	Staff Objections to Follow-Up Questions (1 page) with certificate of service
Jan 9, 1978	62	Letter Lawrence Lanpher regarding witnesses for the California Energy Resources Conservation and Development Commission (4 pages)

Date of Document	Document No.	Title or Description of Document
		VOLUME 22
Jan 11, 1978	1	Letter John Shea (NY) enclosing Motion by the States of New York, Wisconsin and Ohio for a Clarification of the Scope of the Proceeding and an Order Directing the Hearing Board to Accept Certain Questions and Testimony for the Purpose of Possible Amendment of 10 CFR Part 51 with attachments (147 pages) with certificate of service
Jan 13, 1978	2	Letter McGranery opposing cross-examination (3 pages) with certificate of service
Jan 13, 1978	3	Memorandum Howard Shapar to Commissioners regarding proposal to change procedural rules to permit opportunity for cross-examination (4 pages)
Jan 10, 1978	4	Letter Marvin Resnikoff (Sierra Club) requesting to be excused from appearance before the Hearing Board and intentions of submitting questions to Board regarding the economic feasibility of the staff's reprocessing model (1 page)
Jan 12, 1979 (sic)	5	Mailgram P. Walsh and C. Nissl urging Commission to order that the S-3 hearing be postponed until the Commission has ruled on the issue of scope (1 page) with certificate of service
Jan 9, 1978	6	Letter Linker regarding clarification of the hearing procedures (2 pages) with certificate of service
Jan 12, 1978	7	Letter McGranery urging Commission to maintain the current scope of proceeding (3 pages)

Date of Document	Document No.	Title or Description of Document
Jan 12, 1978	8	Letter Pacific Legal Foundation giving address where transcripts are to be mailed (1 page)
Jan 13, 1978	9	Letter NRDC requesting copies of transcripts (1 page)
Jan 12, 1978	10	Letter Pacific Legal Foundation identifying witnesses (11 pages)
Jan 12, 1978	11	Letter James Liverman (DOE) designating DOE representative (1 page)
Jan 13, 1978	12	Letter George Freeman (Hunton and Williams) providing summary statement of position of Baltimore Gas and Electric Company, et al. (6 pages)
Jan 9, 1978	13	Letter NRDC requesting clarification of Memorandum and Order of January 4, 1978 (2 pages)
Jan 10, 1978	14	Letter Ellyn Weiss (UCS) requesting copies of the transcript (1 page)
Jan 11, 1978	15	Letter Emanuel Gordon (AIF) requesting copies of the transcript (1 page)
Jan 16, 1978	16	TRANSCRIPT of Hearing, Bethesda, Maryland, pages 1-119 (120 pages)
Jan 17, 1978	17	TRANSCRIPT of Hearing, Bethesda, Maryland, pages 120-305 (190 pages)
Jan 11, 1978	18	Letter Irwin enclosing summary statement of witnesses (10 pages)
undated	19	Professional Qualifications and Experience of George D. DeBuchananne (U.S. Geological Survey) (2 pages) with certificate of service
		VOLUME 23
Jan 17, 1978	1	Letter McGranery requesting denial of requests to expand scope of proceeding (3 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Jan 12, 1978	2	Letter Lawrence Jones (Pacific Legal Foundation) requesting copies of transcripts (1 page)
Jan 12, 1978	3	Letter McGranery requesting copies of transcripts (1 page)
Jan 15, 1978	4	Letter Irwin requesting copies of transcripts (1 page)
undated	5	Letter Marvin Lewis requesting 10 minutes to testify (1 page) with certificate of service
Jan 17, 1978	6	Letter Lanpher requesting copies of the transcripts (1 page)
Jan 18, 1978	7	TRANSCRIPT of Hearing, Bethesda, Maryland, pages 306-486 (130 pages)
Jan 19, 1978	8	TRANSCRIPT of Hearing, Bethesda, Maryland, pages 487-694 (135 pages)
Jan 18, 1978	9	Letter Shea (NY) regarding change in scope of proceeding (3 pages)
Jan 19, 1978	10	Staff Recommendations for Minor Adjustments to Table S-3 (41 pages) with certificate of service
Jan 21, 1978	11	Tennessee Valley Authority's Response to the January 11, 1978 Motion by the States of New York, Wisconsin, and Ohio Concerning the Scope of the Hearing (11 pages)
Jan 17, 1978	12	Letter Walsh requesting copies of transcripts (1 page) with certificate of service
Jan 18, 1978	13	Letter Gregory A. Thomas (Sierra Club) requesting copies of transcripts (1 page)
		VOLUME 24
Jan 23, 1978	1	TRANSCRIPT of Hearing, Bethesda, Maryland, pages 695-761 (70 pages)
Jan 19, 1978	2	Letter Resnikoff enclosing witness qualifications and requesting transcripts (3 pages)

Date of Document	Document No.	Title or Description of Document
Jan 24, 1978	3	TRANSCRIPT of Hearing, Bethesda, Maryland, pages 762-935 (175 pages)
Jan 25, 1978	4	TRANSCRIPT of Hearing, Bethesda, Maryland, pages 936-990 (60 pages)
Jan 26, 1978	5	Memorandum Chilk to Hearing Board regarding scope and procedures (10 pages) with certificate of service
Jan 19, 1978	6	Letter Harry Otto (Delaware) requesting hearing transcripts (1 page)
Jan 27, 1978	7	Staff Response to Motion by the States of New York, Wisconsin and Ohio for a Clarification of the Scope of this Proceeding (4 pages) with certificate of service
undated	8	Sierra Club Exhibit No. 1—Report on the Applicability of International Radiation Protection (23 pages) with certificate of service
Jan 26, 1978	9	TRANSCRIPT of Hearing, Bethesda, Maryland, pages 991-1067 (60 pages)
		VOLUME 25
Jan 17, 1978	1	Letter Walsh (Wisconsin) requesting copies of transcripts (1 page)
Jan 26, 1978	2	Response of the States of New York, Wisconsin and Ohio to Commonwealth Edison Company, et al., Regarding the Scope of Proceeding and the States' Request for an Order Directing The Hearing Board to Accept Certain Questions and Testimony (5 pages) with certificate of service
Jan 25, 1978	3	Letter Nissl (Ohio) regarding availability of witnesses to answer questions (1 page) with certificate of service
Jan 31, 1978	4	Hearing Board Memorandum and Order (4 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Jan 31, 1978	5	Letter John Shea (NY) with Response of the States of New York, Wisconsin and Ohio to the TVA Regarding the States' Motion on the Scope of Proceeding, etc. (9 pages) with certificate of service
Feb 3, 1978	6	Views of Baltimore Gas and Electric Company, et al. on Consideration of Economic Matters in the Uranium Fuel Cycle Rulemaking (9 pages) with certificate of service
Feb 3, 1978	7	Staff Testimony on Economic Data to Support the Feasibility of the S-3 Model (59 pages) with certificate of service
Jan 31, 1978	8	Letter Ruth Thomas (Environmentalists Inc.) requesting suspension of hearing (2 pages)
undated	9	Letter Marvin Lewis commenting on hearing (1 page) with certificate of service
Jan 31, 1978	10	Letter Ruth Thomas requesting suspension of hearing (2 pages)
Jan 31, 1978	11	Letter Dida McMurray (Environmentalists Inc.) enclosing objections to meeting schedule (2 pages)
Feb 2, 1978	12	Letter Lawrence Jones (Pacific Legal Foundation) enclosing documents supplementing the testimony of Dr. Bernard Cohen (43 pages) with certificate of service
Feb 7, 1978	13	Letter James McGranery responding to Board's request for suggested changes to the design and performance of components assumed by the staff (2 pages) with certificate of service
Feb 2, 1978	14	Reply of the States of New York, Wisconsin, and Ohio to the Staff Regarding the States' Motion on the Scope of Proceeding, etc. (7 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Feb 7, 1978	15	Letter Donald Irwin responding to Board's request relative to staff model (3 pages) with certificate of service
Feb 3, 1978	16	Letter P. Walsh and C. Nissl regarding procedure for questioning of witnesses on behalf of States of Wisconsin and Ohio (7 pages) with certificate of service
Feb 9, 1978	17	Commission Order (3 pages)
Feb 8, 1978	18	Letter Lawrence Jones (Pacific Legal Foundation) with attached reference per Board instruction (14 pages) with certificate of service
Feb 13, 1978	19	Staff Response to Motion for Environmentalists, Inc.—To Suspend Proceedings (1 page) with certificate of service
Feb 9, 1978	20	The NRDC's Motion for Extension of Time (2 pages) with certificate of service
Feb 13, 1978	21	Answers of T. R. Lash to Questions Proposed to NRDC by Hearing Board Memorandum and Order of January 31, 1978 (4 pages)
Feb 15, 1978	22	Answers to Follow-Up Questions Proposed for A. Tamplin (NRDC) (6 pages) with certificate of service
Feb 17, 1978	23	Staff Response to NRDC's Motion for Extension of Time (1 page) with certificate of service
undated	24	Letter Marvin Lewis regarding comments and questions with newsclippings (8 pages)
Feb 15, 1978	25	Answers to Dr. T. LaPorte to Questions Posed to the NRDC by the Hearing Board Memorandum and Order of January 31, 1978 (4 pages)

Date of Document	Document No.	Title or Description of Document
Feb 15, 1978	26	Answers of Dr. J. W. Gofman to Questions Posed to the Sierra Club by the Board Memorandum and Order of January 31, 1978 (25 pages)
Feb 16, 1978	27	California Energy Resources Conservation and Development Commission Responses to Follow-up Questions Posed by Participants (6 pages) with certificate of service
Feb 22, 1978	28	Hearing Board Memorandum and Order (8 pages)
Feb 14, 1978	29	Letter Marvin Lewis regarding certain questions and requests with attachment (8 pages) with certificate of service
Feb 20, 1978	30	Letter Marvin Resnikoff (Sierra Club) with documents and exhibits to be served on parties (228 pages) with certificate of service
		VOLUME 26
Feb 27, 1978	1	Letter Lawrence Jones (Pacific Legal Foundation) with Responses of M. W. Goldsmith to Hearing Board Inquiries of January 24, 1978 (5 pages)
undated	2	Partial Written Response to Questions Addressed to Witnesses (7 pages) with certificate of service
Mar 1, 1978	3	Errata to Staff Economic Testimony (10 pages) with certificate of service
Feb 24, 1978	4	Letter C. Nissl (Ohio) requesting rescheduling of filing date (7 pages) with certificate of service
Mar 3, 1978	5	Hearing Board Order (2 pages) with certificate of service
Mar 8, 1978	6	Hearing Board Order (2 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Mar 2, 1978	7	Letter Marvin Lewis objecting to short time in which to file response to Staff Testimony (1 page)
undated	8	Letter Marvin Lewis regarding economic feasibility of the reprocessing and waste disposal facilities (10 pages) with certificate of service
undated	9	Questions Proposed by Commonwealth Edison Company, et al. for the NRC Staff (3 pages) with certificate of service
Mar 10, 1978	10	Staff Supplemental Documents (1 page) enclosing Staff Draft Site Suitability Criteria (11 pages); Geological Criteria for Radioactive Waste Repositories (DOE Criteria) (20 pages); Report of Finding of the Peer Review of the Site Suitability Criteria for Geologic Disposal of High Level Nuclear Wastes (72 pages) with certificate of service
Mar 10, 1978	11	Statement of H. W. Morton and T. E. Potter Concerning Health Effects Attributable to Segments of the Uranium Fuel Cycle (37 pages) with certificate of service
Mar 9, 1978	12	Proposed Questions of BG&E Co., et al to the Staff Concerning the Staff Testimony on Economic Data (3 pages) with certificate of service
Mar 8, 1978	13	Questions of the State of New York on Staff's Filing of Economic Data to Support the Feasibility of the S-3 Model (13 pages) with certificate of service
Mar 1, 1978	14	Letter Ruth Thomas (Environmentalists) requesting copy of transcript (1 page)

Date of Document	Document No.	Title or Description of Document
Mar 3, 1978	15	Letter Lawrence Lanpher enclosing Status of Nuclear Fuel Reprocessing Spent Fuel Storage and High-Level Waste Disposal (285 pages) with certificate of service
Mar 9, 1978	16	States of Ohio and Wisconsin's Questions to the NRC Staff Regarding Economic Feasibility (2 pages) with certificate of service
undated	17	"Estimates of the Cancer Risk Due to Nuclear Electric Power Generation," by W. M. Ellett and A. B. Richardson (EPA) (17 pages) with certificate of service
Mar 15, 1978	18	Sierra Club Questions Set No. 3 Questions to NRC Staff regarding Economics (2 pages) with certificate of service
Mar 16, 1978	19	States of Wisconsin and Ohio's Objections to Board Intended Procedure as Set Forth in its Memorandum and Order of February 22, 1978 (4 pages) with certificate of service
undated	20	EPA Responses to Hearing Board Memorandum and Order (1 page)
undated	21	EPA Statement of Qualifications of EPA Witnesses Appearing Before the Board on January 26, 1978 (10 pages)
undated	22	EPA Responses to Proposed Questions of November 18, 1977 by NRDC (3 pages)
undated	23	Federal Register—EPA—Radiation Protection Programs—Environmental Radiation Protection Standards for Nuclear Power Operation (1/31/77—42 FR 2858) (5 pages)
undated	24	EPA Responses to Proposed Questions of February 22, 1978 by the Hearing Board (2 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
		VOLUME 27
Mar 22, 1978	1	Staff Responses to Questions on Economic Data (1 page)
undated	1a	Staff Responses to Questions of the State of New York (107 pages)
undated	1b	Staff Responses to Questions of States of Ohio and Wisconsin (6 pages)
undated	1c	Staff Response to Questions of Sierra Club (10 pages)
undated	1d	Staff Response to Questions of Marvin Lewis (26 pages)
undated	1e	Staf Response to Questions of Baltimore Gas and Electric (6 pages)
undated	1f	Staff Response to Questions of Commonwealth Edison Company, et al. (4 pages) with certificate of service
Mar 24, 1978	2	Hearing Board Memorandum and Order (4 pages) with certificate of service
Mar 24, 1978	3	Staff Comments on "Objections" to Board Memorandum and Order of February 22, 1978 (3 pages) with certificate of service
Mar 25, 1978	4	Response of Baltimore Gas and Electric Company, et al. to Objections of the States of Wisconsin and Ohio Concerning Economic Testimony and Hearing Procedures (6 pages) with certificate of service
Mar 28, 1978	5	TRANSCRIPT of Hearing, Bethesda, Maryland, pages 5990-6106 (120 pages)
Mar 29, 1978	6	Hearing Board Memorandum and Order (4 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Mar 29, 1978	7	Staff Submission in Response to Board Request at Transcript Page 6038 (sic) with attachment (5 pages) with certificate of service
Mar 30, 1978	8	Hearing Board Memorandum and Order (3 pages) with certificate of service
Mar 28, 1978	9	TRANSCRIPT of Hearing, Bethesda, Maryland, pages 1068-1184 (CORRECTED COPY) (120 pages)
		VOLUME 28
Mar 30, 1978	1	TRANSCRIPT of Hearing, Bethesda, Maryland, pages 1185-1258 (80 pages)
Mar 30, 1978	2	Letter Marvin Lewis regarding Staff's Answer to Questions on Economic Feasibility with attachments (12 pages) with certificate of service
Mar 25, 1978	3	Letter Marvin Lewis to Romanye Skrutski regarding questions regarding Staff Responses to Questions dated March 22, 1978 (1 page)
Apr 2, 1978	4	Letter Marvin Lewis regarding newsarticle regarding using salt domes for storage (1 page) with certificate of service
Apr 6, 1978	5	Letter Barton Cowan enclosing Statement of California Electric Utilities and Nuclear Industry (84 pages) with certificate of service
undated	6	The States of Ohio and Wisconsin Supplemental Testimony with attachment (30 pages) and with certificate of service
Apr 13, 1978	7	Sierra Club Statement of Intention to Request Cross-Examination (2 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Apr 13, 1978	8	Letter Samuel Chilk to Ruth Thomas (Environmentalists) regarding "Suspension of Hearing on Table S-3" (4 pages) with certificate of service
Apr 13, 1978	9	New York's Statement of Intention to Request Cross-Examination (3 pages) with certificate of service
Apr 12, 1978	10	Letter Helene Linker (NRDC) enclosing NRDC's Notice of Intention to Request Cross-Examination (14 pages) with certificate of service
Apr 5, 1978	11	In Lieu of Oral Testimony—Testimony of Dr. J. E. Kelly on Behalf of the States of Wisconsin and Ohio (12 pages)
Apr 5, 1978	12	Supplemental Testimony of David Deese on Behalf of States of Wisconsin and Ohio (7 pages)
undated	13	Supplementary Testimony of Dr. Irvin C. Bupp on Behalf of the States of Wisconsin and Ohio (7 pages)
Apr 20, 1978	14	TRANSCRIPT of Oral Argument, Bethesda, Maryland, pages 1259-1376 (117 pages)
Apr 20, 1978	15	Responses to the Hearing Board Oral Questions by P. Skinner, P. E. on Behalf of the State of New York with attachments (15 pages) and with certificate of service
Apr 26, 1978	16	NRDC Answer to the Question Concerning the Frigerio and Stowe Report (4 pages)
Apr 28, 1978	17	Letter Lawrence Jones (Pacific Legal Foundation) regarding transcript correction (1 page) with certificate of service
May 4, 1978	18	Hearing Board Memorandum and Order (8 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
May 2, 1978	19	Letter Marvin Lewis responding to Staff's Response to Questions of March 22, 1978 (10 pages) with certificate of service
		VOLUME 29
May 10, 1978	1	Hearing Board Order (1 page) with certificate of service
May 12, 1978	2	Commonwealth Edison Company, et al. Motion for Modification of Hearing Board's May 4, 1978 Memorandum and Order as Amended (5 pages) with certificate of service
May 16, 1978	3	Staff Response to Commonwealth Edison Company, et al., Motion for Modification of Hearing Board May 4, 1978 Memorandum and Order As Amended (2 pages) with certificate of service
May 15, 1978	4	Motion of the Pacific Legal Foundation for Modification of the Hearing Board's Order of May 10, 1978 (3 pages) with certificate of service
May 11, 1978	5	Motion for Extension of Time (NY) (2 pages)
undated	6	Corrections to Transcript (NY) (2 pages) with certificate of service
May 11, 1978	7	Letter M. Lewis regarding rebuttal testimony (1 page) with certificate of service
May 15, 1978	8	NRDC Request for Procedural Assistance (3 pages) with certificate of service
May 17, 1978	9	Response of TVA to Motion of Commonwealth Edison, et al. dated May 12, 1978 (4 pages) with certificate of service
May 23, 1978	10	Letter James Lieberman (Staff) regarding rebuttal testimony (1 page)

Date of Document	Document No.	Title or Description of Document
May 18, 1978	11	Hearing Board Memorandum and Order (2 pages)
May 22, 1978	12	Letter Marvin Lewis requesting procedural assistance (1 page) with certificate of service
May 15, 1978	13	NRDC Request for Procedural Assistance (3 pages) with Geological Survey Circular 779 (19 pages) and with certificate of service
May 26, 1978	14	Testimony of Westinghouse Electric Corporation in Rebuttal to Testimony Filed by M. I. Lewis (2 pages) with certificate of service
Feb 1978	13a	Draft Report of Task Force for Review of Nuclear Waste Management (166 pages)
Apr 4, 1978	13b	Statement of Emilio Varanini, Commissioner—California Energy Resources Conservation and Development Commission Before Hearings of the Subcommittee on Nuclear Regulation Senate Committee on Environment and Public Works on Nuclear Waste Management (22 pages)
Apr 4, 1978	13c	Statement of George D. DeBuchanne [*sic*] Geological Survey (13 pages)
May 26, 1978	15	Rebuttal Testimony of H. W. Morton and T. E. Potter on the Lack of Observable Correlation Between Natural Background Radiation and Cancer Mortality (Baltimore Gas and Electric, et al. and Commonwealth Edison, et al.) (18 pages) with certificate of service
May 26, 1978	16	Rebuttal of Marvin I. Lewis (17 pages) with attachments and with certificate of service

Date of Document	Document No.	Title or Description of Document
May 26, 1978	17	Rebuttal Statement of John W. Gofman (Sierra Club) (23 pages) with certificate of service
May 29, 1978	18	Letter Paul Shemin (NY) enclosing Motion for Leave to File Rebuttal Statement Out of Time (2 pages); Rebuttal Statement on Behalf of the State of New York with attachment (67 pages) and with certificate of service
Jun 6, 1978	19	Letter Walter Eccard (LeBoeuf, Lamb, Leiby and MacRae) to Austin Olney (Delaware) regarding rebuttal testimony of May 26, 1978 in which address was improper (1 page) with certificate of service
		VOLUME 30
Jun 2, 1978	1	Staff Response to State of New York's Motion for Leave to File Rebuttal Statement Out of Time (1 page) with certificate of service
undated	2	Testimony of Westinghouse Electric Corporation in Rebuttal of Testimony Filed by M. I. Lewis with Net Energy from Nuclear Power (140 pages)
Jun 15, 1978	3	Memorandum Chilk to Hearing Board regarding report to the Commission (1 page) with certificate of service
Jun 15, 1978	4	Letter Romayne Skrutski to Marvin Lewis regarding request for DOE document (1 page) with certificate of service
Jun 13, 1978	5	Letter Shea (NY) enclosing Rebuttal Statement on Behalf of the State of New York (67 pages)
Jun 20, 1978	6	Final Submittal from Marvin Lewis (4 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Jun 26, 1978	7	Staff Concluding Statement (97 pages) with certificate of service
Jun 26, 1978	8	Sierra Club Position on the Environmental Effects of the Uranium Fuel Cycle (15 pages) with certificate of service
Jun 27, 1978	9	Motion for Leave to File Out of Time (Commonwealth Edison Company, et al.) (2 pages) with certificate of service
Jun 26, 1978	10	Final Written Statement on Behalf of Commonwealth Edison Company et al. (273 pages) with certificate of service
		VOLUME 31
Jun 26, 1978	1	Final Written Statement of Pacific Legal Foundation (20 pages) with certificate of service
Jun 26, 1978	2	Letter Linker (NRDC) enclosing Closing Statement of the NRDC (60 pages) with certificate of service
undated	3	Final Brief of the States of Ohio and Wisconsin (14 pages) with certificate of service
Jun 26, 1978	4	Concluding Statement of Position on Behalf of Baltimore Gas and Electric Company, et al. (130 pages) with certificate of service
Jun 26, 1978	5	Letter Lanpher regarding California Energy Commission's final comments (2 pages)
Jun 27, 1978	6	Motion for Extension of Time for Final Statement (NY) (2 pages) with certificate of service
Jun 27, 1978	7	Final Statement of the State of New York (42 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Jun 26, 1978	8	Concluding Statement of the Tennessee Valley Authority (31 pages) with certificate of service
Jul 6, 1978	9	Memorandum Hearing Board to Chilk regarding report to the Commission (2 pages) with certificate of service
undated	10	Corrected Version Final Statement of the State of New York (42 pages)
undated	11	Errata to Final Statement of the State of New York (4 pages) with certificate of service
Jul 14, 1978	12	Letter NRDC regarding possible extension of interim rule (5 pages) with certificate of service
Jul 13, 1978	13	Letter Marvin Lewis regarding report by Hearing Board (1 page) with certificate of service
Jul 17, 1978	14	Letter Donald Irwin regarding NRDC Motion for Oral Argument (2 pages)
Jul 21, 1978	15	Letter Lawrence Jones (Pacific Legal Foundation) regarding request of NRDC for oral argument (3 pages)
Jul 26, 1978	16	Letter Freeman requesting that NRDC proposals be denied (9 pages)
Aug 1, 1978	17	Letter Chilk to Marvin Lewis regarding request for early recommendations from Hearing Board (1 page) with certificate of service
Aug 7, 1978	18	Letter James Lieberman (Staff) to Commissioners regarding NRDC Motion for Oral Argument (3 pages) with certificate of service
Aug 9, 1978	19	Letter Marvin Lewis regarding the NRDC request (2 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Aug 29, 1978	20	Letter Linker (NRDC) regarding letter of July 14, 1978 making procedural suggestions (2 pages) with certificate of service
		VOLUME 32
Aug 31, 1978	1	Memorandum Hearing Board to Chilk enclosing Report by the Hearing Board with attachment (142 pages) with certificate of service
Sep 12, 1978	2	Federal Register Notice—Extension of the interim fuel cycle rule (6 pages) with certificate of service
Sep 11, 1978	3	Letter Lawrence Jones (Pacific Legal Foundation) correcting statement made in Hearing Board Report (2 pages)
Sep 9, 1978	4	Letter Marvin Lewis regarding Hearing Board Report (1 page) with certificate of service
Sep 18, 1978	5	States of Ohio and Wisconsin's Correction of Statements in Board's Summary of the Record Regarding Position of States' Witness, Dr. Irvin C. Bupp (3 pages) with certificate of service
Sep 19, 1978	6	Letter Shea (NY) regarding Hearing Board Report (5 pages)
undated	7	Note transmitting Federal Register Notice on Intent to Update WASH-1248 (3 pages)
Oct 19, 1978	8	Commission Order (3 pages) with certificate of service
Oct 26, 1978	9	Memorandum Hearing Board to Chilk enclosing Conclusions and Recommendations of the Hearing Board (87 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Oct 30, 1978	10	Memorandum to All Participants from Hearing Board correcting Hearing Board Memorandum (2 pages) with certificate of service
Nov 3, 1978	11	Letter Marvin Lewis regarding oral presentations by Commission
Nov 3, 1978	12	Letter Marvin Lewis regarding Conclusions and Recommendations of the Hearing Board
Nov 11, 1978	13	Letter Marvin Lewis petitioning that the entire Table S-3 be vacated and eliminated (4 pages)
Nov 16, 1978	14	Staff Response to Commission Order of October 19, 1978 (22 pages) with certificate of service
Nov 16, 1978	15	Letter NRDC regarding Conclusions and Recommendations of the Hearing enclosing Concluding Comments of NRDC Submitted to the Commissioners of the NRC with exhibit (89 pages) with certificate of service
		VOLUME 33
Nov 17, 1978	1	Letter Shea (NY) enclosing the State of New York's Closing Statement to the Commission (45 pages) with certificate of service
Nov 16, 1978	2	Sierra Club Statement to the Commission on the Environmental Effects of the Uranium Fuel Cycle (3 pages)
Jun 26, 1978	3	Sierra Club Position on the Environmental Effects of the Uranium Fuel Cycle (14 pages) with certificate of service
Nov 21, 1978	4	Letter McGranery regarding comments of Commonwealth Edison, et al. on Commission Order of October 19, 1978 (19 pages) with certificate

Date of Document	Document No.	Title or Description of Document
Nov 22, 1978	5	Final Written Statement of Baltimore Gas and Electric Company, et al. to the Commission (14 pages) with certificate of service
Nov 17, 1978	6	Letter Shea (NY) with the State of New York's Closing Statement to the Commission (45 pages) with certificate of service
Nov 20, 1978	7	States of Ohio and Wisconsin's Response to Commission Order of October 19, 1978 (12 pages) with certificate of service
Nov 22, 1978	8	Letter Hendrie to Hearing Board expressing appreciation for discharging its duties with vigor and commendable timeliness (1) page) with certificate of service
Nov 21, 1978	9	Letter Sanger (TVA) to Commissioners regarding Hearing Board's recommendations and conclusions (3 pages) with certificate of service
Dec 15, 1978	10	Commission order (3 pages) with certificate of service
Dec 15, 1978	11	Motion by the States of New York, Wisconsin and Ohio for the Amendment of Table S-3, 10 CFR 51.20(e) (13 pages) with certificate of service
Dec 19, 1978	12	Hearing Board Erratum (Concluding Comments of the NRDC) (2 pages) with certificate of service
Dec 19, 1978	13	Letter Marvin Lewis regarding time oral argument (1 page)
Dec 21, 1978	14	Letter NRDC informing that Helene Linker will make presentation at oral argument (1 page)
Dec. 26, 1978	15	Letter James Murray (Staff) informing that Murray and Frank Miraglia will make presentations (1 page) with certificate of service

Date of Document	Document No.	Title or Description of Document
Dec 21, 1978	16	Letter Donald Irwin informing that Donald Irwin and Dr. Joseph Lieberman will make presentations (1 page)
Dec 27, 1978	17	Letter Chilk to Marvin Lewis regarding rebuttal statements (1 page)
Dec 29, 1978	18	Staff Response to Motion by the States of New York, Wisconsin, and Ohio for the Amendment of Table S-3 (6 pages) with certificate of service
Dec 29, 1978	19	Letter Colleen Nissl (Ohio) informing that Patrick Walsh and Colleen Nissl will present oral argument (1 page) with certificate of service
Dec 27, 1978	20	Letter Shea (NY) informing of presence for oral argument (1 page)
Jan 3, 1979	21	Letter Sanger (TVA) informing that Alvin Gutterman will make presentation (1 page) with certificate of service
Jan 8, 1979	22	Letter Chilk to Parties regarding oral presentations (4 pages) with certificate of service
Jan 12, 1979	23	Letter Donald Irwin informing that Dr. Walton A. Rodger will also present responses to certain questions
Jan 19, 1979	24	TRANSCRIPT of Oral Argument, Washington, D.C., pages 1-181 (182 pages)
		VOLUME 34
Jan 23, 1979	1	Letter John Shea (NY) regarding additional filings in rulemaking (5 pages)
Jan 23, 1979	2	Letter Irwin enclosing concluding remarks of Dr. J. A. Lieberman and W. A. Rodger (10 pages)
Jan 23, 1979	3	Written Statement Supplemental to Oral Presentation on Behalf of Commonwealth Edison Company, et al. (6 pages) with certificate of service

Date of Document	Document No.	Title or Description of Document
Jan 22, 1979	4	Letter Marvin Resnikoff (Sierra Club enclosing Sierra Club Rebuttal Statement to the Commissioners (5 copies)
Feb 7, 1979	5	Request for Corrections to Transcripts of January 19, 1979 (State of New York) (2 pages) with certificate of service
Feb 27, 1979	6	Corrections to the Transcript of January 19, 1979 (NRDC) (1 page)
Mar 13, 1979	7	Federal Register Notice—Extension of the interim fuel cycle rule (4 pages)
Apr 30, 1979	8	Federal Register Notice—Extension of interim fuel cycle rule (2 pages)
May 14, 1979	9	Federal Register Notice—Extension of interim fuel cycle rule (3 pages)
May 29, 1979	10	Federal Register Notice—Extension of the interim fuel cycle rule (2 pages)
Jul 27, 1979	11	Federal Register Notice—Extension of the interim fuel cycle rule (2 pages)
Jul 27, 1979	12	Federal Register Notice—Promulgation of a final fuel cycle rule (73 pages) with certificate of service
Aug 3, 1979	13	Letter Marvin Lewis regarding Final Fuel Cycle Rule (1 page) with certificate of service
Aug 27, 1979	14	Letter Helene Linker (NRDC) requesting the Commission supplement its July 27, 1979 Order
Sep 25, 1979	15	Federal Register Notice—Correction of errors appearing in published final rule (2 pages)

[PORTIONS OF INITIAL STATEMENT OF NRDC WITNESS TERRY R. LASH (October 3, 1977)*]

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE HEARING BOARD

Docket No. RM 50-3

IN THE MATTER OF

AMENDMENT OF 10 C.F.R. Part 51
LICENSING OF PRODUCTION AND
UTILIZATION FACILITIES
(Environmental Effects of the
Uranium Fuel Cycle)

STATEMENT OF TERRY R. LASH

Submitted by:

Natural Resources Defense
Council, Inc.
2345 Yale Street
Palo Alto, California 94306

October 3, 1977

[* These portions consist of pages 3 and 7-13 of NRDC Witness Terry R. Lash's Initial Statement. See Certified Index of the Administrative Record in Docket Nos. 79-2110 and 79-2131 at Vol. 17, Doc. No. 1.]

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The standards for judging the adequacy of the proposed rule are the standards that have been established under the National Environmental Policy Act, including, for example, the requirements for full disclosure of uncertainties and cumulative impacts, and for presentation of information in terms understandable by laymen. Table S-3 fails totally to meet these standards. The Table does not disclose numerous uncertainties and gaps in the NRC's analysis; cumulative impacts are ignored completely; the environmental consequences of failure to implement the assumed but yet to be developed, technologies are totally absent; the trade-offs between economic costs and environmental impacts are not evaluated; and radiological impacts are not explained in terms laymen can relate to human health.

Moreover, many of these same deficiencies are found in the two documents supporting Table S-3. To the extent that the documents attempt to consider some of the above critical issues, they do so wholly inadequately. For instance, although NUREG-0216 contains an analysis of the health effects that would be caused by the assumed levels of radioactive releases, the estimates of induced cancers are widely optimistic, as is shown in the separate statements of Drs. Tamplin and Cochran.

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One of NRDC's major objections to the use of Table S-3 without an accompanying narrative is that a single numerical table, standing by itself, provides no indication of the massive uncertainties and assumptions in the calculations made to derive the reported numbers. For instance, lack of experience with satisfactory practices for long-term disposal of high-level waste, results in two fundamental uncertainties: (1) the uncertainty as to the actual feasibility of implementing a safe operational waste disposal system, and (2) the uncertainty in our

ability to predict the behavior of wastes once emplaced in a geologic repository.

As NRDC pointed out earlier, one important result of the Task Force's failure to examine the implementation processes required to provide certain technologies is to neglect consideration of the consequences that would occur if the assumed waste management technologies were not available when needed. The Task Force argues, however, that it was "charged with estimating reasonably expectable environmental impacts", but was not asked "to consider whether technologies would be employed, nor was it asked to address the adequacy of implementational systems for the technology." [8] The Task Force further states, however, that,

> "It is implicitly the Task Force's judgment that these technologies will materialize; to analyze their failure to do so would not seem warranted." [9]

No supporting evidence is presented to give credence to this implicit judgment; and, more importantly, much information is ignored in arriving at such a position. Given the past history of waste management, particularly the so far fruitless search for a geologic repository site, NRDC believes that the Nuclear Regulatory Commission has a responsibility to make explicit the assumptions underlying its judgment that the needed technologies will materialize and to describe these assumptions fully in the EIS's for individual nuclear power reactors. Indeed, consideration of the probability of implementation of waste management systems and full disclosure of the consequences of failing to implement the assumed technologies must be integral parts of the Commission's environmental assessment for the fundamental reason that the impacts of failure to have the needed technologies would increase the

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[8] NUREG-0216, at p. 3-117.

[9] *Id.*

environmental impacts associated with reprocessing and waste management dramatically.

The Task Force admits, in a bit of understatement, that, "The history of nuclear waste management . . . might be used to argue that the implementation system for waste management has not worked perfectly in the past." [10] But the Task Force dismisses this argument with the assertion that ". . .that system was changed by the Energy Reorganization Act of 1974 into a system intended to provide greater assurance of success." [11] However, in my opinion, the division of the responsibilities of the former Atomic Energy Commission into the Energy Research and Development Administration and the Nuclear Regulatory Commission does not provide adequate grounds for optimism about improvements in the future handling of radioactive waste. Even idealistically, the reorganization alone cannot solve the kinds of implementational problems that have occurred in the past. In fact, there have been very serious difficulties in locating a waste disposal facility under ERDA's program, as discussed below.

In essence, the Task Force is arguing by false premise. To illustrate this point about argument by false premise, consider the assumptions of the Task Force that long-lived radioactive wastes will be buried in a deep geological formation, probably bedded salt, before significant amounts can escape into the general environment, and that once emplaced only insignificant amounts of the wastes will enter the environment and expose people to radiation. The Task Force recognized that the "[r]esults of . . . [long-term risk] assessment [for waste repositories] are not subject to proof in the usual demonstration sense [and that] [t]heir evaluation will depend on one's degree of confidence in the validity of the result and on subjective

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[10] *Id.*

[11] *Id.*

judgments as to what levels of risk are acceptable." (NUREG-0116, page 4-94). Nonetheless, the Task Force made the judgment that the "long-term risk of failure of the repository [is] negligible." (NUREG-0116, page 2-18) And, only this rosy judgment is reflected in Table S-3.

The Task Force's assumption that a geologic repository will be established in a bedded salt formation is overly optimistic, and it does not encompass other possible future realities. The analysis omits entirely any consideration of the possibility that long-lived radioactive wastes may not be deposited in a geological formation with the characteristics assumed by the Task Force. Such a possibility is real, because, as recent events have shown, "[l]ocal political attitudes now loom as large as geological criteria in the government's increasingly troubled attempt to find sites for the permanent disposal of radioactive wastes." [12] Due to local political opposition, salt formations in the states of Michigan and Louisiana, which until recently were prime candidates for waste repositories, may not be available for disposal of wastes. The salt formations near Carlsbad, New Mexico, the only other salt deposits apparently under serious consideration for waste disposal, are not now planned for use in disposing of commercial wastes. Even if current plans were modified to include the possibility of using commercial high-level wastes in the Wastes Isolation Pilot Plant, there is significant uncertainty that the salt formation near Carlsbad can meet the siting criterion of not interfering with other, valuable natural resources, such as potash. The *Science* magazine article cited above suggests that the other two sites under serious consideration for the disposal of long-lived commercial wastes are the basaltic formation beneath the Hanford Reservation in Washington and the

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[12] Carter, "Nuclear Wastes: Popular Antipathy Narrows Search for Disposal Sites," *Science 197*, 1265 (23 September 1977).

agrillaceous rock formation under the Nevada Test Site. However, as the Task Force states, there is even less information about the long-term risks of buring [*sic*] wastes in these non-salt media than there is for bedded salt (NUREG-0116, page 4-72), for which the Task Force recognizes "there are still uncertainties" (NUREG-0116, page 4-94). Thus, if as appears possible, indeed, some would even say likely, bedded salt deposits are not available for timely disposal of long-lived wastes, the technical judgment that the long-term risks are "negligible" would be based on very little evidence.

The basic point here is that the Task Force's failure to consider local politics invalidates its implicit judgment that the assumed technologies (in this case, a high-level waste repository in an acceptable bedded salt formation) will be available and that it is inappropriate to analyze the impacts under the assumption that the technologies will not materialize. (NUREG-0216, page 3-117) The importance of these "institutional" barriers to successful waste management and disposal is recognized by virtually every study group, except for the NRC's Task Force.[13] This major gap in the analysis will only serve to reinforce the public's existing lack of confidence and skepticism, and to lead to increased local political opposition to the establishment of repositories proposed in the future.

The historical situation at West Valley, and the developing political problems in establishing a geological repository, lead me to disagree vigorously with the Task Force's belief that the ". . . trends in technology and action with regard to nuclear wastes indicated a direction that could be used as a basis for some confidence." [14] In contrast to the Task Force's claim to have reviewed several unref-

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[13] See, e.g., Report of the Nuclear Energy Policy Study Group, *Nuclear Power Issues and Choices*, page 244 (Ballinger Publishing Company, 1977).

[14] NUREG-0216, at p. 3.

erenced documents, ". . . none [of which] is pessimistic with regard to having a successful implementation system," [15] a number of reports have been published recently which are less sanguine. For instance, Mason Willrich, a careful student of radioactive waste management issues, in a report for ERDA concluded, *inter alia*, that

> "The existing organization for radioactive waste management is likely to be unworkable if left unchanged."
>
> . . .
>
> "The existing framework for radioactive waste regulation is likely to be ineffective if left unchanged." [16]

The second major uncertainty not reflected in the numbers in Table S-3 concerns the estimation of the level of containment afforded by geological formations. The Task Force seems to be overly confident about the ability of geological formations to isolate long-lived wastes for the required periods of time. Since there is no experience with such a facility, the projections of waste behavior over long periods of time are basically conjectural, and the uncertainty is necessarily great. The existence and importance of these uncertainties must be described in narrative form in order to provide meaningful assessment of the impacts of a light water reactor.

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[15] *Id.*

[16] "Radioactive Waste Management and Regulation," Energy Laboratory Report No. MIT-EL-76-011, pages 1-5, 1-6 (December 1976). It is worth noting that these two conclusions were supported by Norman C. Rasmussen, Chairman of, and David J. Rose, Professor in, the MIT Nuclear Engineering Department. (page i)

[PORTIONS OF INITIAL STATEMENT OF
NRDC WITNESS TODD R. LAPORTE
(October 3, 1977)*]

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE HEARING BOARD

Docket No. RM 50-3

IN THE MATTER OF
AMENDMENT OF 10 C.F.R. PART 51
LICENSING OF PRODUCTION AND
UTILIZATION FACILITIES

(Environmental Effects of the Uranium Fuel Cycle)

STATEMENT OF TODD R. LA PORTE

ON INCREASING SCALE AND SYSTEM RELIABILITY IN THE MANAGEMENT OF RADIOACTIVE WASTES: REQUISITES FOR CREDIBLE ENVIRONMENT AND COST-BENEFIT ANALYSIS

Submitted by:

Natural Resources
Defense Council, Inc.
2345 Yale Street
Palo Alto, California 94306

October 3, 1977

[* These portions consist of pages 2 through 11, l. 3 and 14, l. 18 through 16, l. 22. See Certified Index of the Administrative Record in Docket Nos. 79-2110 and 79-2131 at Vol. 17, Doc. No. 1.]

Before addressing the substantive issues of this statement, I begin with a brief description of my background and experience in the radioactive waste management field. I am an Associate Professor of Political Science and Associate Director of the Institute of Government Studies at the University of California at Berkeley. Over the past decade, I have been extensively involved in research assessing the impacts of technological developments on organization management systems and on the regions into which they are deployed.

Most pertinent to this proceeding, I have applied this systems analysis approach to the technological developments in radioactive waste management systems. For five years I have served as a consultant to NASA, assessing the socio-political aspects of radioactive waste management, and other technological developments. I was the principal investigator for a study, entitled "Space Disposal of Nuclear Wastes: Socio-Political Aspects," which was completed for NASA in December 1976. I am also a member of the National Academy of Sciences—National Research Council Committee on Radioactive Waste Management. I have thoroughly reviewed the literature assessing the socio-political implications of waste management.

In this brief statement, I address an aspect of radioactive waste reprocessing, management and disposal that seemingly has, based upon the NRC's Task Force Report, entitled the *Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle* (NUREG-0116), the related NUREG-0216, and the supporting literature, escaped the NRC's notice thus far in considerations of the environmental and cost-benefit analyses associated with the development of nuclear power plants. This is the matter of the reliability of the waste management system as it is scaled up in size to handle the larger amounts of wastes in various forms antici-

pated from increasing numbers of power plants in the next fifty to one hundred years.

The primary emphasis in the radioactive waste field thus far has been on the technological and management processes for reprocessing wastes, storing them for an interim period and then removing them from any contact with all life forms. These considerations always have placed primary emphasis on the far future—at least one thousand years. These assessments have asked how we can develop highly reliable, socially acceptable, technical systems so effective that they will nearly eliminate for at least 1,000 years the long-term risks of radioactive wastes to future generations.

These considerations of potential risks in the distant future are, of course, very important to decisionmaking in radioactive waste management. However, there is a more immediate set of considerations that have equally important implications for environmental, socioeconomic and health effects of waste management. These considerations are associated with what might be called the "ten year problems," that is, the problems involved with the handling of spent fuel during the period of ten or so years after it is removed from the reactor and when the wastes must be handled, transported, changed in form, stored, solidified and, finally, entombed for geologically long periods of time. It is probably within the approximately ten year period before final burial that most of the major mistakes having negative social, economic, occupational and health effects will be made. It is within this period that there is the greatest potential for accidental releases, and the concomitant damage will be done to the next four to six generations if there are difficulties with the disposal systems. This is the period when the technologies are most closely involved with human beings, workers, communities along the transportation routes, are most susceptible to human error, and pose the greatest threats of human exposure.

Based on my review of the radioactive waste literature and knowledge of the field, I believe that for an adequate estimate of the environmental, socioeconomic and health effects of radioactive wastes from nuclear power development and for less speculative estimates of the costs of nuclear power than are currently set forth in Table S-3 and the accompanying documents, NUREG-0116 and NUREG-0216, much more precise information should be available about (1) the operation and human organization of the system, (2) the system's overall size, (3) the resources likely to be needed to construct and run it, and (4) the special programs necessary to make sure that the people involved perform at the high level of reliability necessary to prevent accidents. In effect, the technical revisions included in Table S-3, especially those related to transportation and to occupational exposures, must take more fully into account the operation of the waste management system as the volume of wastes increases greatly.

My analysis of the existing literature indicates that the most important information now missing from studies of radioactive waste management systems is information about the effects on operations as the number of plants—we can think of them as waste producers—grows rapidly. This gap in available information is crucial because the challenges of increasing scale are likely to be considerable. Not only will the sheer volume of waste requiring management and disposal escalate substantially; but, more importantly, the fundamental character and complexity of the waste management system may be transformed as it responds to increased demands of scale. In view of the future complexity of waste management systems as the scale of operations increases, it seems quite clear that the analytical method of Table S-3, NUREG-0116 and NUREG-0216 of simple extrapolation from past experience, based as it is on relatively very small scale systems, is an unsuitable basis for future estimates of costs. Nor does the use of model, non-operational facilities to derive

the numerical values in Table S-3 suffice as a basis to estimate the environmental and sociological impacts of the future waste management systems, because, among other things, they do not take into account complexity of scale.

The absence of large-scale operational information has a significant political effect. It is the characteristic of the apparently rapidly increasing scale of operations and concomitant increasing potential for error that is the basis for considerable public uneasiness. In the absence of information about the scale of operations, the public and its leaders perceive that a number of critical issues have been left in a state of great uncertainty. Some of the unsettling questions that have been raised and left unanswered in the debate and that point to potential occurrences that could alter the cost calculations of nuclear energy can be briefly typified as follows:

1. There is a considerable uncertainty that the near fail-safe operations of radioactive waste systems that will apparently be required can be attained in practice. Some alternative waste management steps seem demanding of high skill and very consistent behavior. As the volumes of wastes increase, the most crucial scarce resource may be people who are sufficiently skilled and who can be motivated to perform continuously at extraordinarily high levels of reliability even though the jobs will be routine and boring. This situation may require special training programs and special social status to maintain motivation and dedication. Systems analysis assessments in other industrial areas have demonstrated that when the numbers of people required grows to keep pace with increased volume, the quality of performance goes down.

This potential for increased human error has not been thoroughly addressed with respect to a scaled-up waste management system in NUREG-0116 and NUREG-0216. However, because a serious mistake resulting in a major

release of radioactive materials has such potentially large health and safety consequences, even though such a release may be quite speculative, a responsible assessment of the costs of nuclear energy should take into account the costs of assuring very high operational reliability. Such an accounting is absent in the analysis of NUREG-0116 and NUREG-0216.

2. Impacts on communities adjacent to nuclear facilities, to waste processing operations and to the transportation routes are problematic and are assessed inadequately in the cost information displayed in Table S-3, particularly in the context of a scaled-up waste management system. We do know from past industrial experiences that large scale operations usually have strong effects on the economic make-up of adjacent communities. In an economic sense, local communities often gain a measure of benefit *if* the new facilities actually increase the number of jobs available to those already residing in the affected community. But it is not clear that radioactive waste processing, storage and disposal operations automatically provide employment of this kind. Rather, it seems more likely that the major proportion of new jobs may require importing people already trained in the special skills relevant to the functional requirements of waste management and disposal. To the degree this is the case, the economic benefits to the "impacted communities" may be reduced.

The economic and social burdens placed on these adjacent communities should be considered. In the case of waste management security requirements, the transportation requirements, the additional potential exposure to health hazards, may all create burdens that outweigh the benefits of the nuclear system. But again, my principal point is that uncertainty continues due in part to lack of information about the operational requirements as *the scale* of the waste management challenge increases. This information must be ascertained, or at least more accurately estimated, for an adequate cost-benefit assessment.

Table S-3 is devoid of any information relevant to this important concern; and the supporting documents, NUREG-0116 and NUREG-0216, do not provide the required analysis.

3. The pattern of economic impacts and costs of the systems on a national level are also subject to the same uncertainty. There has been no readily accessible analysis on a national level of the economic questions related to the capital and operating costs of a large scale waste management system, including the transportation system, storage mines, etc., or to the costs of developing the technology and facilities for waste management necessary to handle the wastes issuing from the large number of waste producers envisioned for a mature system of uranium-fueled light water reactors in the future. It is probable that the capital investment for an adequate waste management system will be substantial, probably requiring public tax subsidies. When combined with the investments necessary to construct and operate the nuclear plants which produce wastes, it is still an unanswered question whether the level of capital investment would be so high as to exact an unacceptable opportunity cost on the nation as a whole. Again, in the absence of information concerning the likely operational requirements, as the waste system goes to much larger scale, which requires more resources for operation, current calculations of costs, as reflected in Table S-3, do not accurately reflect the full impacts and costs of nuclear power, and they cannot provide decisionmakers with a sufficient background to determine whether to proceed with the licensing of many more nuclear power plants.

There are other important areas of questions and uncertainties. For instance, there are unpredictable political consequences of small breaches of the system or of small accidents. The potential for error and release undoubtedly increases with the increasing complexity of scale. However, disclosing that radioactive materials have escaped

from the system, or reporting any event which could be interpreted as leading to a potential escape, would very likely prompt strong reactions from people living within a reasonable distance of waste processing facilities or storage areas. Such reports would likely galvanize opposition to further activities in the communities adjacent to nuclear and waste handling facilities and transport routes. Yet failure to disclose such incidents *immediately* increases the public's distrust, and raises questions about the veracity of the governmental agencies and/or private firms involved. This poses a very difficult, nearly no-win situation for both the operators and regulators of waste facilities. Such impairment in the relationship between the government and the public must certainly be considered essentially as costs of error. Nonetheless, the current evaluation of waste impacts in Table S-3 lacks an assessment of these socio-political costs.

And, of course, there are a host of international relations problems associated with plans for disposal of wastes anywhere other than within the continental limits of the United States, such as beneath the seabed or in deep space. Disposal of U.S. wastes outside the limits of the U.S., however technically sensible, could open the government at least in the short term, to politically motivated attacks. The outlines of international reaction to U.S. waste disposal policy awaits the clarification of that policy, but there will unmistakably be complicating difficulties if international waters or air space are involved, especially if wastes from abroad are imported into the United States for reprocessing. The toll upon international relations resulting from waste management alternatives should not be excluded in estimating the cost of expanding nuclear power. Neither NUREG-0116 nor NUREG-0216 includes such considerations. Table S-3 is also inadequate to this extent.

These issues are a sampling of the areas inadequately addressed in Table S-3 with respect to their socio-economic,

political and environmental impacts as the scale of operations increases greatly. There is, underlying these uncertainties, the conviction that the larger the technological organizational system the less reliable it is likely to be, and the more costly reliable performance is to attain. Therefore, responsible systems analysis must assess the *problems of reliability of systems as they increase in scale and complexity.* This is particularly the case in the area of radioactive waste disposal where the consequences of accidents or laxness resulting from an escalation in scale portends dramatic and serious environmental and health impacts.

Below are some guides useful in assembling the types of information that are currently lacking in the NRC's assessment and that should be included in the analysis of radioactive waste management systems in order to provide credible estimates of environmental, socioeconomic and health effects for those considering whether more nuclear power plants should be built.

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Information on Exposure Probabilities and Error Anticipation

There remain at least two other types of information necessary for credible cost-benefit and environmental impact estimates—the likelihood that the life forms will be exposed to radioactive hazards and the planned responses to anticipated error.

The first type requires the development of an index of social exposure to radioactive hazards. In each step of the way there are two kinds of probabilities that combine for an index of social exposure. The first is the probability that a technical component of the system will fail. There is a probability factor that can be attached to potential system failures at each of the stages. The second prob-

ability is some likelihood that human beings or other life forms would be exposed to the release. This probability ranges from zero to a quite high probability. An index of these two probabilities related to the complex set of steps in waste management processes could be called an index of social exposures to radioactive hazard. Such an index would be important in improving the accuracy of Table S-3 and establishing the true costs of nuclear energy.

[*Waste Management System*]

Finally, there is the matter of error anticipation. With the scale and complexity of operations likely to be necessary, there seems to be little question that significant errors can be expected. Given the severe consequences of errors and accidents, it would be irresponsible to develop the systems on the assumption that errors would not occur. Therefore, it is imperative as part of the cost-benefit analysis to include the costs of error identifying procedures as well as the costs of the errors themselves, so that errors can be detected when they are still small and then rectified when they are found. This means that there should be in the original design of the technological processes a way of telling when things are going wrong. But the more difficult task is the job of monitoring the system for the quite unexpected. There is every reason to query industry and ERDA about the costs of reversing the damage done if different types of accidents do occur. Without such analyses the estimation of costs will be too low—how low awaits further analysis. Such an analysis is not now part of the record or, as far as I can tell, included in any of the various calculations performed in formulating Table S-3; or is such an analysis a part of the discussion of any topic in the Topical Outline for these Proceedings.

In sum, the Nuclear Regulatory Commission's analysis of the waste management system underestimates the environmental impacts of that system because it fails to

address the impact of each reactor in relation to its contribution to the growing volume of waste requiring disposal. Additional data based on predictions of a scaled-up waste management system are necessary to assess the true impacts and costs of the waste management portion of the nuclear fuel cycle.

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[NRC STAFF RESPONSES TO NRDC QUESTIONS 17, 22, and 26 (December 2, 1977)*]

Answer from NRC
From Participant NRDC
Participants Method of
Identifying Question 17,
Chap. 2, NUREG 0116

Question:

17. On *page 2-9 of NUREG-0116*, the NRC staff states that, "While knowledge about other alternatives is more limited, we believe the salt-bed analysis to be reasonably representative of impacts that would result from any appropriately designed geological emplacement."

    a. If the knowledge about other alternative [*sic*] is so limited, how can the staff be assured that the salt-bed impacts are reasonably representative of impacts from any geological disposal system?

Answer:

First, knowledge of other media while limited is not "so limited" that no conclusions can be drawn. Studies by other countries (e.g., Sweden, Italy) and other groups (e.g., the APS) have concluded that other formations look promising.

Surface facilities needed during the operational phase for a repository are essentially independent of the sub-

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[* The responses are to NRDC questions 17, 22 and 26 with respect to NUREG-0116, Ch. 2. See Certified Index of the Administrative Record in Docket Nos. 79-2110 and 79-2131 at Vol. 19, Doc. No. 8.]

surface repository system. Impacts from such facilities can therefore be expected to be essentially the same for any site. Transportation impacts might differ, however, depending on location.

Assessments of potential long-term impacts are made using generic methods that can be applied to any repository. Parameters used in the assessments will of course be specific to the site and repository concept. Results of the assessments will be used as feedback to adjust the system concept (e.g., site or design) to assure that potential long-term impacts are in the same range as those for an approved bedded salt repository.

Given that no analysis to date has calculated any substantial release from the repository, and thus the long-term impacts are entered into the tables as zero, we can postulate no different impacts for any geologic formation.

Answer from NRC
From Participant NRDC
Participants Method of
Identifying Question 22,
Chap. 2, NUREG 0116

Question:

22. On *page 2-10 of NUREG 0116*, the staff states that, "The environmental impacts listed in Table 2.8 for geologic disposal in salt are those accrued during waste emplacement and up to the time the mine is scaled [*sic*]."

    a. Does the first statement quoted above mean that the values for the radiological effluents listed on *page 2-29* in Table 2.8 do not include any releases from events occurring after the facility is decommissioned?

Answer:

Correct, the radiological effluents listed on page 2-29 in Table 2.8 do not include any releases as a result of events occurring after the repository is sealed. The judgment leading to this assumption is listed on page 2-18 of NUREG-0116.

Answer from NRC
From Participant NRDC
Participants Method of
Identifying Question Ch. 2,
NUREG-0116, #26

Question

26. On *pages 2-12 and 2-13* of NUREG-0116, the staff states that, "The disposal of unprocessed spent fuel has received less attention and should therefore be considered in a less-developed technological state than the geologic storage of HLW."

a. Does the staff believe that the values in Table 2.10 for the impacts of spent fuel disposal are as accurate and certain as the values for the impacts of HLW disposal?

b. If the answer to "a" is no, how do the values in Table 2.10 reflect uncertainties in the information base grom [sic] which they are estimated?

c. If the answer to "a" is yes, what does the staff believe is the range in impacts attributable to this uncertainty? Why is no such range included in the table under the impacts of spent fuel disposal?

Answer:

a. Yes.—While more is known about the design and waste rock interactions for the disposal of high level wastes than is known for the disposal of spent fuel, both have considerable uncertainties in the long term. (See Page 2-18 of NUREG-0116.) While there are additional uncertainties inherent in the disposal of spent fuel, (See also page 2-18 of NUREG-0116.) we have found no basis to believe that the values given are less accurate than waste disposal. In fact, as pointed out by several questioners and as noted in NUREG-0116 and elsewhere in responses to questions in this proceeding, the values for radiological impact in the long term have been entered into the tables as zero. Values for other environ-

mental impacts are virtually the same for either high level waste or spent fuel. Only the long term heat loading was noted as giving rise to a possible change in long term land commitment. This was taken into account in NUREG-0116, Chapter 4, pp. 4-103 & 4-114.

b. Not Applicable

c. In general the staff made conservative assumptions with regard to what would occur in actual operation of the repository. Further, the staff is unable to calculate a range in the impacts attributable to the uncertainty. Such a calculation can only be the result of sophisticated analyses for which preparations are only just begun.

[USGS RESPONSES TO
NRDC FIRST ROUND QUESTIONS
(December 9, 1977)*]

RESPONSE TO QUESTIONS SUBMITTED BY THE PARTICIPANT NATURAL RESOURCES DEFENSE COUNCIL FOR THE U.S. GEOLOGICAL SURVEY

[* These are USGS responses to all NRDC first-round questions. See Certified Index of the Administrative Record in Docket Nos. 79-2110 and 79-2131 at Vol. 20, Doc. No. 12.]

Answer from USGS
From Participant NRDC
Participant method of
identifying Question 1

Question 1

1. a. Has the U.S. Nuclear Regulatory Commission (NRC) established such geologic criteria and procedures? If not, has the NRC requested USGS assistance in their preparation? What advice in this regard has USGS given NRC?

   b. Has the Department of Energy (DOE) established such geologic criteria and procedures? Should geologic criteria be established prior to selecting a site for a proposed repository?

   c. Has the USGS established such geologic criteria and procedures? If so, what are they? If not, does the USGS intend to do so?

   d. Does the USGS believe that the environmental impacts of waste disposal can be assessed realistically in the absence of such geologic criteria and procedure? Why?

Answer

1. a. The USGS is not aware of any geologic criteria, or procedures for site verification of geologic criteria, issued by the NRC.

   Members of the NRC staff have discussed with the USGS staff the need for such criteria and subsequent verification. These discussions were generic in nature and did not result in an agreement or concurrence on which specific items should be included.

   The USGS staff has made itself available to the NRC staff to discuss specific problems which the

NRC staff might have. Members of the USGS staff have, when requested, worked closely with NRC contractors on the subject of risk analysis, geochemical reactions in different geologic media and participation in NRC-sponsored workshop for state review of suite suitability criteria for high-level radioactive waste repositories.

b. The USGS staff has reviewed and commented on a draft proposal of hydrogeologic parameters that should be considered in the development of criteria for the selection of high-level waste repositories. It is the USGS understanding that criteria will be issued in December 1977 or January 1978. The term "selecting a site" can be interpreted as including all phases of site selection that occurred between the conception of a repository need to the actual physical construction of a repository. The USGS believes that specific hydrogeologic criteria should be developed and issued prior to the actual construction and development of a proposed repository. The early regional reconnaissance phase of locating a repository does not require site specific criteria.

c. The USGS does not have the legislative authority or responsibility for establishing geologic criteria and procedures for verification of such criteria for high-level waste repositories.

The USGS is currently developing hydrogeologic parameters that can be used in the selection of future low-level radioactive waste disposal sites. It is expected these parameters will be available in early 1981.

d. The USGS does not believe that the environmental impacts of waste disposal can be realistically assessed in the absence of criteria and procedure.

The basic problem that must be addressed in all assessments of impact considerations of geologic disposal of high-level waste can be stated as follows. High-level waste which is not in mechanical, thermal, or chemical equilibrium with its natural environment is placed in a complex geologic host with the object of not allowing physical and(or) chemical migration of radionuclides away from the disposal site into the biosphere in hazardous concentrations. It follows that multi-component physical-chemical systems which will develop in and around the repository as a result of waste-rock interaction must be completely understood to avoid unforeseen effects. The effect of natural disturbances on emplaced waste must also be considered.

An evaluation of the effect of waste emplacement is necessary to ultimately assess all possible failure modes. Failure may result from both natural and waste-introduced processes, occurring independently or in conjunction with each other. Basic information on the effect of disposal in host media and its geologic regions, data from laboratory studies, and the result of predictive containment and transport models all contribute to a thorough understanding of possible failure.

Answer from USGS
From Participant NRDC
Participant method of
identifying Question 2

Question 2

2. a. Does the USGS believe the analysis of the environmental impacts of deep geologic waste disposal NUREG-0116 is realistic? Does USGS think that there are greater uncertainties than reflected in the judgment of the task force that prepared NUREG-0116? What are the uncertainties surrounding deep geologic disposal of high-level wastes?

   b. Does the USGS believe that the model land-burial facilities for low-level waste described in NUREG-0116 accurately reflects existing low-level burial facilities? If not, how do existing facilities differ from the model facility? Are the environmental impacts of existing facilities greater than for the model facility?

   c. Does the USGS believe that the model low-level burial facilities accurately describe future actual low-level burial facilities? What would be the environmental impacts of future actual facilities?

Answer

2. a. The question has to be answered first by clarifying what is meant by realism and uncertainty. All activities carry risk. The risk of deep geologic disposal of radioactive waste cannot be measured from past experience but must be assessed from predictive models of waste behavior after it is emplaced. These models will be realistic if they take account of all possible events and processes which can lead to release of radionuclides and if the

stated uncertainties in measuring the probabilities of these events and the rates of these processes are accurate reflections of current knowledge.

Section 4.4.2 of NUREG-0116 is realistic in the sense that all broad classes of possible events and processes are discussed. However, very few specific events and processes are discussed. In particular, Group 3, section 4.4.2.1, geologic events or processes caused by the repository or the waste, are given only brief discussion not indicative of the many potential processes and interactions that may take place. The effect of the repository and the waste on rock salt are of special concern because salt is under active consideration as the site of a repository. Fluids in equilibrium with salt will most likely be brines and these brines may cause substantial loss of strength of the salt. In addition, brines have a low capacity for fixation of any released radionuclides. Predictive models for waste behavior in salt must therefore assess the probability that the workings will be flooded and the consequences of possible movement of the waste.

It is not possible to judge the uncertainties stated in section 4.4.2. of NUREG-0116 because no numbers are assigned to any of the uncertainties discussed. The text indicates many gaps in knowledge suggesting that in general the present uncertainties of predictive modeling of waste behaviour are high. USGS has not assessed the uncertainties either but wishes to emphasize three points. (1) While the past can be used as a guide to the future, the rates of some geologic processes have been known to change dramatically with time so that estimates of future rates must be assigned a higher uncertainty than would be the case from simple extrapolation from the past. (2) There is bound to be a large uncertainty in many parts of

the model because we cannot research the individual parts over the times of concern and because there are certain to be unidentified interactions between processes. (3) In the radionuclide transport models, there is a vast amount of data yet to be collected on the flow path and its properties—especially on chemical effects between the medium traversed and the waste under non-equilibrium and non-isothermal conditions. Included are such effects as ion exchange, precipitation and solution under various conditions of Eh and pH and surface chemical effects in fractured media.

It should also be pointed out that high uncertainty in any component of a waste containment system does not necessarily mean that the entire system entails especially high risk. In a system with multiple barriers to radionuclide migration, confidence in one barrier may alleviate uncertainty in another. For example, if it is known with a high degree of confidence that the flow path to the biosphere has a high retardation capability, then lack of knowledge about the rate at which waste may be leached into circulating round [*sic*] water does not increase the overall uncertainty of the system. Such sensitivity analyses as these will have to be made for each natural waste containment system under consideration.

In summary, NUREG-0116 is an accurate general statement about risks from geologic disposal of radioactive waste, but it is no substitute for a detailed risk assessment of a specific site.

b. The USGS believes that the model land-burial facility for low-level waste as described does not reflect existing low-level burial facilities.

Of the five commercial burial facilities that are being studied by the USGS, two facilities have a

potential for very high erosion; several facilities have perched water and(or) regional water tables less than 50 feet below the land surface and the total possible seasonal fluctuation of the water table are as yet unknown; one or more facilities have less than 30 feet depth of unconsolidated materials for trench construction; two or more facilities have permeabilities of cover material permitting water accumulation in completed disposal trenches; at two or more facilities the permeability of the material in which the trenches are constructed is not sufficiently uniform to make measurements that will allow reasonable inference as to the water and radionuclide content between existing monitoring points.

Preliminary investigations suggest that the environmental impacts of several of the existing facilities are greater than for the model facilities described in NUREG-0116.

c. The USGS believes that the model low-level burial facility describes the general physical geohydrological characteristics of a potential future low-level burial facility. It should be recognized that the model facility does not address the problem of how these described geohydrologic characteristics should be related to the longevity of waste products. It is believed that the environmental impacts of future low-level burial facilities will depend not only on the geohydrological characteristics or parameters of the facility itself but will also be dependent upon the nature of the waste products buried at the waste disposal sites. All waste nuclides cannot be buried at all facilities.

Answer from USGS
From Participant NRDC
Participant method of
identifying Question 3

Question 3

3. On *page two*, it is also stated that, "The Department and its Survey scientists are concerned that a scientifically sound solution be developed for disposing of radioactive wastes. . . ."

   a. Are there any deficiencies in DOE's program that may prevent it from developing the desired "scientifically sound solution"? If so, what are they and what recommendations does USGS have for correcting those deficiencies?

   b. Does USGS believe that there are geologic formations other than salt that may be "better" for disposal of high-level wastes? If so, what are they and why would they be "better"?

   c. What are the deficiencies of bedded salt and domed salt for high-level waste disposal?

Answer

3. a. DOE's program is a major national effort that would lead to a sound scientifically defensible solution if all of the proposed components can be completed in time to be utilized in repository design.

   The USGS has submitted comprehensive proposals to DOE and has received funding support for portions of those proposals. We have continuing dialogue with DOE and its contractors as to further work needed and application of the geological, geochemical, geophysical and hydrological data that are being generated.

   b. Recent work by the USGS indicates that anhydrite may have a number of advantages not

present in halite as a medium for high-level waste disposal. It should be emphasized that analysis of all potential media are not complete so it is not yet possible to quantify the risks involved in the using of any medium or to say which is "best". Anhydrite has the advantage that it possesses retrograde solubility below 230° C so that fluids in the immediate vicinity of hot waste will migrate away from, not toward, the waste. Anhydrite has a thermal conductivity close to that of halite but is more brittle. One considerable advantage of anhydrite is its property of fixing water in intermediate hydrated compounds, so it should act to keep water away from the wastes; in addition, many elements from the waste, including the actinides, form relatively insoluble sulfate inhibiting migration of radionuclides away from the repository. Other possible media are granitic rocks, shale, zeolitized tufts, and thick unsaturated alluvium, but investigations of these rock types have not proceeded far enough to permit detailed comparison with salt.

c. The basic problem with salt, or halite, is its solubility. Brine in equilibrium with halite at 0° C contains 25% by weight halite. Mixtures of solid halite and brine tend to be mechanically weak compared to dry halite; preliminary data indicate that a small amount of brine may have a relatively large weakening effect. If impurities are present, either those occurring naturally or introduced from the waste, or if the temperature is higher than 0° C, even more salt is dissolved in the brine, and the same amount of water has a larger effect. As with all potential disposal media, there are fewer problems with salt as long as it remains completely dry. In salt systems, however, the introduction of even small amounts of water at elevated temperatures could cause serious loss of mechanical strength, loss of retrievability, and

conceivably, movement of waste. Brines are also highly corrosive and would eventually destroy metal canisters and cladding and begin leaching the waste. Available data indicate that in brine-salt mixtures, many of the radionuclides will remain in solution rather than being fixed in solid phases; thus, these elements are freed for potential transport if the repository site is breached.

[USGS RESPONSES TO
NRDC FOLLOW-UP QUESTIONS
(December 23, 1977)*]

RESPONSE TO FOLLOW-UP QUESTIONS SUBMITTED DECEMBER 16, 1977, BY THE PARTICIPANT NATURAL RESOURCES DEFENSE COUNCIL FOR THE U.S. GEOLOGICAL SURVEY

[* These are USGS responses to all NRDC follow-up questions. See Certified Index of the Administrative Record in Docket Nos. 79-2110 and 79-2131 at Vol. 21, Doc. No. 19.]

Answer from USGS
From Participant NRDC
Participant method of
identifying Question 1

Question 1

1. In response to NRDC's Question 2(a), the USGS indicated that there is high uncertainty in predictions of future behavior of high-level wastes emplaced in geological formations; but that the uncertainty does not necessarily imply high risk. In light of the complexities in assessing the degree of uncertainty and risk, does USGS believe that Table S-3 by itself adequately alerts potential readers of EIS's on individual reactors, including lay-people, to those uncertainties and their possible significance? If not, how would USGS supplement Table S-3 so that it adequately informed the public about the uncertainties surrounding the disposal of future high-level radioactive wastes in geological formations? In particular, would USGS favor a narrative accompanying the table to explain, among other things, the uncertainties in predictions of the geological behavior of radioactive wastes?

Answer

1. Table S-3 by itself clearly does not convey an appreciation of the risks involved in geologic disposal of high-level radioactive wastes or the uncertainties involved in determining such risks. The uncertainties involved in predicting the geological behavior of radioactive wastes and of a repository are probably best conveyed by narrative material, but whether such material should be incorporated in Federal regulations is a legal question that the USGS is not qualified to answer.

Answer from USGS
From Participant NRDC
Participant method of
identifying Question 2

Question 2

2.a. In response to NRDC's Question 3(a), the USGS indicated DOE's program is sound, ". . . if all of the proposed components can be completed in time to be utilized in repository design." Does USGS believe that all of the proposed components can be completed reasonably in conformance with DOE's 1985 deadline for establishment of the first repository to receive commercial high-level wastes? If not, what components may not be completed fully in time? What would be the earliest reasonable date that a repository could be available if all of the proposed components are completed fully before the repository is designed?

b. Has the USGS published any of its recent work on anhydrite as a medium for high-level waste disposal? If so, please identify these publications and submit copies for the record in this proceeding. If not, when will published information be available and when can it be submitted for the record in this proceeding?

c. In light of the problems of halite as a medium for disposal of high-level wastes, does the USGS recommend against primary consideration of halite for location of high-level waste disposal repository? If not, why not?

Answer

2.a. The USGS does not have responsibility to comment on the investigation of the many political, legal, financial, and technological factors that enter into the time-tables for developing a commercial waste repository. The question does not seem relevant to

the matter of Federal regulations concerning the environmental impact of a nuclear reactor.

b. The USGS is collecting data on the chemistry of evaporite-brine systems involving halite, anhydrite and other components, but none has been published as yet. The estimated date for publication is July 1978. Such data are but part of the data bank required for assessing the risks involved in geologic disposal of high-level radioactive waste. It is not apparent these or the other data required should be part of the hearing record on licensing of nuclear facilities.

c. As stated in our response to question 3(b), propounded by NRDC on October 31, it is not possible at this time to confidently assess the risks in connection with any medium presently under consideration. That assessment must be made by DOE as license applicant and NRC in the regulator's role. The USGS can measure many of the needed data on the behavior of various media and is presently doing this for several potential media for use in risk assessment by these agencies.

[EPA TESTIMONY
ON
January 16, 1978 *]

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[70] Chairman GLASER: Environmental Protection Agency.

DR. ROWE: I am William D. Rowe, Deputy Assistant Administrator for Environmental Programs.

Mr. Chairman, I apologize for being late, and members of the hearing Board. Traffic on East-West Highway and Wisconsin Avenue is indeed difficult today.

I welcome this opportunity to appear before you to discuss EPA's discussion with regard to these proceedings.

For the record, I will submit a litter [*sic*] of comments we have made previously and the fact that we have had exchanges with NRC in which they have responded to our comments.

But despite this interchange there are still a few issues which have not been resolved to our satisfaction.

I should say that EPA is concerned with this rulemaking for several reasons.

First of all, EPA has major responsibilities under NEPA to review environmental impact statements.

In addition, EPA's unique responsibility in the Federal Establishment to provide guidance to all federal agencies on radiation protection matters. This authority was transferred to us in the Radiation Council in 1970, as encoded in the Atomic Energy Act, section 273(H) [*sic*].

In addition, we have the responsibility to establish standards and regulations which may directly limit the impacts enumerated in Table S-3.

[* The entire EPA testimony on January 16, 1978 is presented Tr. 70, l. 1 through 78, l. 12. See Certified Index of the Administrative Record in Docket Nos. 79-2110 and 79-2131 at Vol. 22, Doc. No. 16.]

[71] These authorities included the Atomic Energy Act, the Clear [*sic*] Air Act, Federa [*sic*] Water Pollution Control Act and Resources Conservation Recovery Act.

EPA has three concerns regarding Table S-3 which have not been resolved in spite of the considerable dialogue referred to earlier in my statement.

The first concern which is not minor, but can be dispensed with easily. On January 13, 1977, EPA issued environmental protection standards for nuclear operations. These standards which become effective in greater steps between December 1, 1979, and January 1, 1983, will have a major effect on Table S-3 which should be reflected by the table either in the form of a separate column or footnote.

We find it hard to believe that any facility for which an EIS is prepared following this rulemaking will be in operation prior to the effective date of this standard.

Our next major concern relates first to the——

CHAIRMAN GLASER: Is it the Environmental Protection Agency's understanding that Table S-3 values to be developed over the rule will be final and will never be reevaluated at any other point?

DR. ROWE: No, we will certainly review our environmental standard and update that standard periodically. We feel that each of these become—through due process become law, they will certainly be the limitations for which the fuel [72]cycle is set up for.

CHAIRMAN GLASER: I don't know if you understood my question. Is it your understanding that the NRC Table S-3 which will be the outgrowth of this proceeding will be final and will never be reviewed again by the NRC?

DR. ROWE. No.

CHAIRMAN GLASER: All right.

DR. ROWE: But we do feel by the time it has any impact, those standards will be in effect.

Our second concern relates to the rulemaking relative to requirements of NEPA and EIS process and, secondly.

to the adequacy of the table entries themselves as a conservatively complete estimate of the impact of the balance of the fuel cycle for use in NEPA review of individual nuclear power stations.

It is our understanding that the Commission has decided with the concurrence of the Court not to subject this rulemaking to the NEPA process.

We thus believe that it is appropriate to view this rulemaking as limited to a conservative assessment of the impact of the balance of the fuel vehicle [*sic*]. However it is not, in our view, the purpose of this rulemaking to make a determination of the environmental acceptability of that impact.

That assessment, making the use of Table S-3, [73] is properly carried out as part of the NEPA review of the alternatives of each nuclear power station.

With this understanding of the purpose of this rulemaking, EPA would agree that environmental impact statements generically addressing Table S-3 is not necessary.

[74] I will now proceed to our views on the adequacy of Table S-3 as it now stands.

Regarding this latter and final major concern, it is our strongly held view that the calculations of environmental impact for radioactivity releases to the environment now providing by Table S3 is seriously deficient in at least three respects.

First, the assessment of dose is arbitrarily determined at 50 years when in fact the impact of these environmental contaminants persist for much longer periods.

Secondly, these assessments have been arbitrarily limited to impact on U.S. populations for a variety of radionuclides that have well recognized worldwide impact.

There are ample precedents and examples of more adequate assessments some of which have been presented in this hearing.

My point is that it is not justified to ignore these future impacts just because they are difficult to deal with and it is certainly not the responsibility of this rulemaking to pass judgment on their acceptability.

First we need the complete assessment. That is our present task. Then we can proceed in the appropriate forum to the judgments.

Finally, for the case of radon, we do not believe that the assessments of source terms are complete nor that the [75] pathways to man, dosimetry and health impact have adequately been assessed. It is our understanding that these calculations are presently being revised.

We would like to receive and comment on these revised calculations before this rule-making is concluded.

In summary, we believe Table S3 in its present form represents neither an adequate nor conservative assessment of the environmental impact of planned release for the balance of the cycle.

I want to thank you for this opportunity to present our position on these matters.

Unfortunately, I will not be able to be present to respond personally to your questions next week, but I will ensure that members of the Staff that can answer these questions will be here.

CHAIRMAN GLASER: Sir, I think in view of your remarks this afternon that perhaps you ought to communicate what the Environmental Protection Agency wants, you ought to communicate with the Staff, because as I understand it the information you are seeking is not part of this proceeding.

You have reference to some other calculations which the Staff is making I believe that are outside the scope of this proceeding.

DR. ROWE: We think they are particularly pertinent to Table S3, impact of this fuel cycle.

[76] CHAIRMAN GLASER: I am making the suggestion that EPA follow whatever procedures it follows

to contact the Nuclear Regulatory Commission and obtain what information you need.

DR. ROWE: I think we have. Our problem is that we have had communications twice back and forth with the Staff on this matter. These are elements that we do not feel yet have been adequately resolved.

We still will continue to work with the Staff to resolve these, don't misunderstand me. We have worked with them. But at this time these particular areas in Table S3 remain incomplete as far as we are concerned.

DR. BUCK: I think, Dr. Rowe, the main problem here I think is the one about radon, which is the head of the cycle shall we say.

DR. ROWE: Yes.

DR. BUCK: And mining. That was specifically omitted from this rule-making hearing, there are further calculations being done on this. This was okayed by the court as I recall it.

There are further discussions or analyses being made by the Staff on this. If I recall it correctly, the Commission has stated that it will hold a further hearing on the front end of the cycle and the Staff can correct me if I am wrong on this.

[77] But my understanding is that that was specifically omitted from this rule-making hearing.

MR. MURRAY: That is our understanding, Dr. Buck.

DR. ROWE: Okay, that will be acceptable as long as it is being handled separately.

DR. BUCK: That is my understanding, sir.

DR. ROWE: I would have no problems with that.

MR. BRIGGS: When your witnesses appear, will they be able to tell us what values they think should be put in Table S3 in place of those that are proposed by the Staff?

DR. ROWE: In terms of what the impact will be from our standards, certainly.

In terms of what is the proper time of dose commitment to be used and what the proper worldwide population involved is, there are judgments to be made.

The problem is we do not think these judgments have been approached and specified adequately at the present time.

The question I am suggesting is some of the radionuclides involved are very long-lived.

MR. BRIGGS: Yes, I understand that part.

DR. ROWE: Okay, the present dose commitment is done only for 50 years. The question we have is whether that 50 years is adequate.

I don't know if that is a question that has been addressed properly. We and other people have used different [78]numbers.

We are not saying ours are right either. And we are suggesting that the issue of what is a propper [*sic*] time is certainly open for consideration to measure the impact.

MR. BRIGGS: Fine.

Will your witnesses be able to tell what the numbers should be on the basis of the method that they prefer for calculating that?

DR. ROWE: I believe they will be able to do that, yes.

MR. BRIGGS: Thank you.

DR. ROWE: Thank you.

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**[PORTIONS OF NRC STAFF TESTIMONY
ON
January 19, 1978 *]**

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[531] WITNESS BISHOP: I would like to make a summary remark and then perhaps Mr. Hewitt can talk of the relationship we have had with the DOE on the criteria.

First, we must develop our criteria independent of NRC [*sic*] and so have not asked them for very much input in that regard.

On the other hand, we have offered input to them about our criteria on a number of occasions. We must enter a formal licensing process with them as an applicant.

To take their work as part of the basis for our own establishment of an independent criteria would be to make something of a sham out of that licensing process. And [532] so we have been very careful in how we accept that information from them. But we have had contacts where they have listened to what we are doing, and we assume have factored that into their own thinking process and Mr. Hewitt, I think, can talk about some of those contacts and how they have interacted. I might add, we are not establishint [*sic*] those criteria in this proceeding, but rather looking at the environmental impacts that we would expect from a facility of the type envisioned by the Department of Energy.

BY CHAIRMAN GLASER:

Q. To get to the type envisaged, you have to find out the criteria. How do you get to that point, the general idea of what is involved?

[* The portions of NRC testimony on January 19, 1978 consist of Tr. 531, l. 15 through 534, l. 23, 584, l. 13 through l. 24, 595, l. 4 through 603, l. 6, and 628, l. 1 through 632, l. 16. See Certified Index of the Administrative Record in Docket Nos. 79-2110 and 79-2131 at Vol. 23, Doc. No. 8.]

A. (Witness Bishop) If that logic prevails, Mr. Chairman, I think you would say we could not establish any environmental impacts under NEPA in advance of knowing all the detailed criteria that will obtain and be used in the licensing process in the future.

Q. I don't think we are talking about detailed criteria, pages after pages of specifications. I think what we want is a general idea of what is involved.

A. Now, that we can offer. We can provide you with a list of the principles under which we are operating, not numerical values, but again the principles. That is something Mr. Hewitt can address.

[533] Q. I think that would be very helpful. How about the principles under which DOE is operating, can you give us that?

A. I am sorry?

Q. How about the principles under which the DOE is operating? Would you be able to give us those too after you have checked with their people to see whether there is objection?

A. We will certainly make that attempt.

Q. I assume that is how they are operating too, not criteria fully defined, but some broad principles which enable them to at least start.

A. Yes.

BY DR. BUCK:

Q. Before you go into that, I might again go back to the USGS paper and read the sentecnes [*sic*] following the ones I read. It says much ongoing research in USGS is directed at helping to establish such criteria. The hearings on the environmental effects of waste management must address the question of whether in the absence of final criterial [*sic*] a definitive assessment of such impacts can be made. It is this very point that is concerning us.

A. May I comment on that statement in the USGS testimony there? The Staff has never purported to be

making a definitive estimate of the environmental impacts. Rather, [534] the best estimate available today. And so I am not sure we would disagree, given the word "definitive," with the statement on the part of the USGS.

We recognize in a number of places both in the original documents and in the testimonies, or excuse me, in the questions and answers, that there are considerable remaining uncertainties.

And what we did was select a model which we felt reasonably represents what is likely to be suggested to us by the Department of Energy and estimated to the best of our ability, the environmental impacts from that model. We did not presuppose to know what our criteria would be in their final form in so doing, because those criteria are being developed in a separate and distinct process which will enter a rulemaking hearing similar to this on a separate track sometime soon.

It was just pointed out to me, by the way, that already on the record as reference 56, in NUREG 0116, is a document called "Site Selection Factors for the Bedded Salt Pilot Plant at Oak Ridge," an Oak Ridge technical memo, dated 1973. So to the extent that those have been carried along, that is already on the record by the then ERDA, or I guess that was back in the days of the AEC.

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[584] Q. How many sites are likely to be required to handle all the fuel bundles or all the high-level waste from the reactors that are constructed between now and the year 2000; do you have any idea?

A. (Witness Lincoln) 500 gigawatts in 200 [*sic*]? I think using, as a basis, the kind of growth curves that range up to the four to five hundred gigawatt years online in 200 [*sic*], I believe following those reactors for something like a 30 to 40-year period of life, so we are now talking about repositories just needed not up to the year 2000, but to follow that entire economy through the LWR economy, if you will, is something on the order of

ten to 12, thirteen. That would be probably limited by, I suspect, in our modal [585] facility, at least a U-only recycle economy, and it would be about 10 percent less than that if it was a spent fuel economy.

[586] Q. How do you judge what limits should be put on the size of the repository, the number of reactors, for instance, that it should be able to accommodate? Is that in your criteria?

A. (Witness Hewitt) It is not in the site suitability criteria we have here. It is something that would be considered in the design criteria.

Again, it is going to be site specific, probably more of a thermal consideration than a radionuclide migration consideration.

A. (Witness Lincoln) The basis of the modifications of Table S-3, I don't know the legal phrases for it, but in essence the widget you got this morning, whatever you want to call it.

MR. MURRAY: Suggestions?

CHAIRMAN GLASER: We are going to ask that Mr. Murray provide copies of that Sandia report to the reporter for inclusion in the transcript that we have been asking questions about, particularly Table 7.1.

Would you see that that is done sometime today, Mr. Murray?

MR. MURRAY: No problem at all in doing that, Mr. Chairman.

(The document follows)

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[595] BY DR. BUCK:

Q. The NRDC question 7—rather 2-26, starting on page 771 has several questions here, some of which have been answered.

But in answer to the range of impacts and the range of impacts on the fuel disposal, particularly the spent fuel disposal, the Staff gives an answer. In general, Staff

made conservative assumptions with regard to what would occur in actual operation of the repository.

Further the Staff is unable to calculate a range of the impacts attributable to the uncertainty. Such calculations can only be the result of sophisticated analysis for which preparations are only just begun.

What sort of preparations are you talking about here in your sophisticated analysis?

A. (Witness Bishop) We have with us this afternoon the gentleman who is undertaking some of the development of those methodologies, Dr. Peter McGrath.

Q. Could he give us a brief description of what he is doing?

A. Surely.

Q. Okay.

[596] A. (Witness McGrath) At the current time we are doing very little other than preparing for some analysis that would try to answer some of these questions. It fits into a larger program in developing—and that program is for the development of analytical tools to study the long-term containment ability of a repository in a deep geologic formation.

Obviously, if one is going to put spent fuel in a repository as opposed to solidified high-level waste several changes are necessitated by that. One is one can have a slightly different emplacement density. The drifts are going to have to be designed somewhat differently, the handling equipment, because we are talking now about a much longer package than high-level waste, which will change the thermal loading, nature of the thermal loading of the repository, the degree to which one might have compaction and settling offset by thermal expansion.

What that will do to the overlying rock formations which in most cases will protect, have been protecting the repository from, rather the salt formation if we are talking about salt, from water.

The presence of the gases that certainly many of the fuel elements will still contain when they are in place,

permeability of the medium to those gases, how they might migrate, whether that migration might start before we actually have full compaction of the backfilled areas. [597] If the backfilled area is not fully compacted by the time the gas might start migrating then obviously it is going to migrate much faster. The collection of data to answer those questions such as the gas permeability of the solids, et cetera, we have no answer at this time.

We have come up with probably a fairly incomplete list of the things we have to look at and are still trying to, let's say, better define what that list should be.

[598] Q. What do you plan to do, contract out some of the test requirements, and so on, to others, or are you going to try to do all this by mathematical analyses?

A. Well, I am with Sandia Laboratories and we are the contractors, essentially. We are not in a position to do experiments ourselves, except for fairly limited experiments.

The description of the site has to be done by mathematical models, because we are talking about fairly long time periods. The data is collected from many soruces [*sic*], other personnel within the laboratory system, USGS, and we essentially utilize the data that exists today or that could be obtained in the very near future, like a year or less.

Q. That would be part of the data that is being collected, shall we say, in the experimental sites now by DOE, or is any such data being collected at the moment?

A. (Witness Bishop) Let me try to answer that. First, let me elaborate just a bit on what Dr. McGrath said and then come back to your question about what data is being collected.

One of the things that Dr. McGrath and his team have committed to is to provide us with a list of essential information that they think must be provided to their model, in order for our understanding of the repository to be complete.

We will then ask others or the Sandia Laboratories [599] to do the requisite experiments, many of them labo-

ratory, some of them in the field, to provide that information.

We have already begun instructing our research organization to begin the collecting of that information, and, as Dr. McGrath said, the list is yet incomplete.

Bakc [*sic*] to your final question there about what DOE is doing. To our understanding, DOE is collecting on-site information at several sites, one, the Carlsbad site, the Waste Isolation Pilot Plant, in which they have a number of drillholes already and are analyzing the core samples, have done some fairly substantial testing of seismic nature on the stratigraphy, and so on.

They are also looking at a number of other sites, the set of reports that I referred to this morning that we have just received and placed in the public document room indicates the kind of analysis they will be doing on those other sites. So, yes, a lot of that information is being collected in the field studies by DOE.

In addition, as I am sure you will hear from the U.S. Geologic Survey, they are anticipating a fairly substantial effort over the next few years in also collecting fundamental geological information relevant to geologic disposal and which would, of course fit our mathematical models.

Q. Do you plan this program to run along in parallel [600] with, shall we say, the initial determination of a site and development of that site, so that the data will be, shall we say, applied to that location?

A. Yes. And let me qualify that yes with a little bit of our philosophical approach.

We can always, on an ad hoc basis, judge an application on the basis of whatever information is presented to us and reach some sort of conclusion. Sometimes we would find that additional information is required. We are hoping that we can be ahead of that game to some extent by having done our own analysis in advance in a generic way and, to some extent, perhaps, in a model site way, and ask ourselves in advance what kind of informa-

tion we want, prepare such things as standard review plans, as outlines for environmental statements, and so on.

DR. BUCK: I don't know whether you have any more, Mr. Briggs, I was going to go on with what is wrong with the Kansas site, but do you have anything more before we get into that?

MR. BRIGGS: Yes, I think there are two or three things I would like to ask about, first.

BY MR. BRIGGS:

Q. The first one has to do with iodine-129. Is it contemplated that iodine-129 will be stored in the—in this repository also?

[601] A. (Witness Bishop) That's the assumption we made, yes.

Q. And is——

A. (Witness Miraglia) The iodine-129 in the spent fuel is released after emplacement in the repository.

Q. And over what period of time do you assume that it is released, any particular period of time?

A. The assumption that was made was that the iodine-129 would be released shortly before backfill.

Q. Shortly before backfill?

A. (Witness Bishop) Before or after?

A. (Witness Miraglia) We assumed it is all released to the atmosphere.

Q. And you would like the same assumption then for any iodine-129 that was taken out of the off gas streams from a reprocessing plant?

A. No, sir, in the reprocessing plant there is the treatment of gases. Therefore, the source term for iodine-129 for the uranium recycle case is different.

Q. But you have to do something with that iodine-129 that you recover in a reprocessing plant.

A. That's correct.

Q. That would go into the repository also?

A. That's right and the mercuric nitrate scrubbers, the waste from there.

[602] Q. That would also be released then from the repository?

A. No, in that particular cycle, it would be in the repository as a solid waste.

Q. And it would be in such form that the rise in temperature in the repository wouldn't release it?

A. At that point in time the migration of that would be dependent upon the diffusion of the nuclide through the media.

Q. That brings up another point.

Since the canisters are assumed to be corroded away, the next assumption must be that somehow, the wastes mix with the salt over a period of time; is that right?

A. (Witness Bishop) I think that was the prudent assumption, but I am not sure that it makes any difference to the analysis. Nor am I sure that we directly analyzed that.

Q. Well, the point then is that you don't think it makes any difference to the analysis whether the fission products and the plutonium, if plutonium is present, mix in with the bulk of the salt; is that the idea?

A. The assumption was that we take no credit for the waste form or canister and, therefore, that that would be the situation which obtains and that's the scenario for which the calculation then was done.

Q. Well, the assumptions that I am concerned about [603] here are the following.

It seems to me that one of the results is that one expects essentially no migration of fission products out of the waste repository, and no migration of plutonium out of the waste repository; is that not right?

A. That's correct.

[628] A. (Witness McGrath) In terms of the meteorite impact they were able to come up with reasonably small bounds on the probability that, and then the consequences of such a meteorite impact was a function of the meteorite size and the time after closure of the repository which the meteorite struck.

In the first couple hundred years of course the consequences locally were quite severe. The global consequences were fairly similar to what were—or probably having now as a result of the atmospheric testing of weapons.

But in terms of the amount of material injected in the atmosphere it was of the same order.

Volcanism, which the volcano appeared very close to the repository or actually right over it, this is close by a couple of kilometers, we had similar types of consequences.

The probabilities I believe were somewhat lower than the meteorite. Or that order.

A. (Witness Lincoln) 10 to the minus—the meteorite is two times 10 to the minus 14 per year. We don't have the volcano in here.

A. (Witness McGrath) All right. They tried to assess the probability of a fault connecting aquifer with the disposal horizon. What did they come up with, 10 to the minus nine per year? 10 to the minus 11 for faulting. The [629] consequences for that were quite a bit lower. It is a higher probability but a lower consequence event because the—first you have the time to dissolve the salt away, the time to transport, the delay of the transported material, et cetera.

There they calculated consequences of the order of background radiation exposure to people. If somebody tapped in the aquifer directly and drew the water out in a well the consequences were of the order of 10 times higher.

BY MR. BRIGGS:

Q. You people have examined Claiborne & Gera's study closely, I assume?

A. (Witness Bishop) Yes, I think probably most of us at this table have read it and studied it quite closely.

Q. Can I assume that you are well acquainted with the geologic characteristics of the area which that study represented?

A. I guess the answer to that is yes, we are pretty familiar.

Q. Would that area be reasonably representative of your model, the area that would have your model repository in it?

A. The answer seems to be yes.

Q. Did you find out anything about that area that would cause you to decide that it was not acceptable as an area for a repository?

[630] A. We were not looking at a particular geologic area.

Once again, this was not a proceeding to license a particular repository.

Q. Yes, I understand. But the problem seems to be we would like to know, if one could find out, whether there was anything about that area, or anything about the Lyons, Kansas area, that one could say now would make either one of them unacceptable for a repository.

A. The answer is generically, no, we didn't spot any such thing.

But specifically there were problems at Lyons, Kansas that cropped up that were not adequately addressed. We can go on to that if you wish, now.

Q. I think it would be a good idea. We are interested, are there the multiple barriers in Lyons, Kansas, and the other features that seem to be necessary for a satisfactory site?

A. Perhaps I can make a few opening remarks about Lyons, Kansas and then see where your questions then would carry us.

I would remind the Board that in NUREG-0216—or 116, the Staff did a very brief review of the development of policy for commercial high-level wastes.

And part of that review was of the Lyons, Kansas site and development of the policy there. And review that [631] very briefly.

First of all the site was originally chosen for experiments to validate the concept that the national academy had proposed of disposal in bedded salt.

Following the establishment of that experiment there was a fire at Rocky Flats causing a lot of plutonium contaminated trash to be shipped to Idaho.

The Idaho officials were unwilling to have the commitment in Idaho and asked the AEC to please find a permanent place for that as soon as possible.

Given some rather good results of the early experiments at Lyons, Kansas, the AEC decided to press for making that a permanent repository for those wastes.

At the same time some Kansas geologists and other scientists found what they considered to be technical failings with the Lyons, Kansas site itself. And that raised enough political doubts, that in 1972 the AEC authorization bill specifically forbade the AEC to make that a permanent repository.

At about the same time a commercial mining company nearby, others have details on that, reported the loss of some water injected for solution mining which raised the question of whether there might be in fact cavities that could connect to the Lyons mine itself.

As a result of all of this pressure, the AEC [632] withdrew the idea in 1972 for making that a permanent repository. The decisions made were really quite political, but there were some complexities of a technical nature that were not specifically addressed in the entire body of technical literature at that time, at least to everybody's satisfaction.

We can follow on on any of the lines along that that you care to pursue.

The point I would make before we do, though, is that this Staff, the NRC Staff, has not specifically looked at the Lyons, Kansas site or any other state to compare it against our developing criteria for the purpose of establishing the acceptability of that site or any other site.

That is simply not part of this proceeding as far as we are concerned and it does prejudge a future licensing decision.

[USGS TESTIMONY
ON
January 23, 1978 *]

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[699] WITNESS DE BUCHANANNE: George D. DeBuchananne, United States Geological Survey.

WITNESS TRASK: Noel J. Trask, U.S. Geological Survey.

BOARD EXAMINATION

BY DR. BUCK:

Q Dr. DeBuchananne, I want to ask a few questions on some expansions of answers to the answers that you gave to NRDC questions.

In their question 1, NRDC asked about geological criteria and procedures established by NRC, and also about those established by DOE. And your answer was that the USGS is not aware of any geological criteria or procedures for site verification of geologic criteria issued by NRC.

Now, do you have any knowledge of any criteria that have been issued or are used as working documents for DOE?

A (Witness DeBuchananne) DOE, in the Office of Waste Isolation, did submit a series of criteria which they asked us to review.

Q Do you remember what sort of criteria those were? What did they consist of, and so on?

A These were geologic—hydrogeologic types of statements.

[* This consists of the entire USGS testimony on January 23, 1978, Tr. 699, l. 3 through 735, l. 23. See Certified Index of the Administrative Record in Docket Nos. 79-2110 and 79-2131 at Vol. 24, Doc. No. 1.]

[700] Q And are you now talking about the deep geologic repositories? Is that correct?

A Yes, sir. Yes, sir.

Q Are you working at all for DOE in the way of investigating criteria, or investigating problems with the depository [*sic*]?

A The Geological Survey does have a program with DOE in which we are doing work of a reconaissance nature in some cases, more site-specific in others, and some generic laboratory experiments.

Q I wonder if you would mind giving us a brief description of some of those projects, the general nature of the projects, please?

A A typical example of a reconaissance type of study would be, say, at the Paradox Salt in Utah where our field geologists have gone into the field and done some field mapping, surface mapping. Our geohydrologists are working in regional groundwater investigations in this area. That is about the status of the program at this time. It will be expanded into more detail as DOE proceeds down the road.

Q Have you done work then only on one site?

A No, sir. We have done this type of work at Utah. We've done some work in New Mexico. We're doing work in Louisiana on salt domes, and have recently initiated some programs in Mississippi and Texas on salt domes. We've done [701]a reconnaissance type of study on the Salina Salt Basin in New York, Ohio and Michigan—that Appalachian Salina Basin.

Q Have you done any work on the Carlsbad repository?

A In New Mexico?

Q Yes.

A Yes, sir, we have done a—USGS did the original regional study of the permean [*sic*] salt which DOE used the basic work to select sites in New Mexico to be further expanded for additional studies.

Q All right. Now, in doing this work did DOE set up preliminary criteria that they were looking for, the types of things they were looking for? Or how did you go about getting the contract, starting it, and so on?

A In the Carlsbad, New Mexico permean [*sic*] salt the DOE set up some general criteria that they would like, areas in which they were then drilling, or where you might find salt of such and such a thickness—these were a very general, broad type of criteria.

Q And did you go about locating the salt areas—for example, the Carlsbad salt bed area? Or had that already been done?

A As a result of that program with DOE, the USGS indicated, as I remember, about six areas in the permean [*sic*] salt basin which appeared to meet these very broad, general criteria that DOE had set up.

[702] Q I see. Okay.

Let's go back to schedule for just a moment. You say the work that you're doing is to be expanded in the near future, is that correct?

A We have an ongoing program which is an expansion of this, or progressing. As we complete one phase, we report to DOE. Then they say if they would like us to do something else.

Q I see. Now, this expansion—you mentioned several sites before where you had done preliminary surveys. Is the work that's coming up in the future—will that be more detailed analyses of those areas, or out looking for further areas—or both?

A This would be more detailed work at the general area of investigation. That is, in the Salina Basin DOE—we are waiting for DOE to select from other criteria they have areas which they might want to go further and expand and investigate further.

Q Of the sites you've already looked at?

A Of the broad general basin of New York, Ohio and Michigan, yes, sir.

Q I see. Okay.

Now, on the further answer to NRDC's question 1, you say, "The USGS believes that specific hydrogeologic criteria should be developed and issued prior to the actual [703] construction and development of a proposed repository."

What specific criteria are you looking for here? This is detailed, site-specific criteria, I presume?

A This is what we had reference to in that case, and it should be explained that the USGS is not involved in setting criteria for—

Q I understand.

A This is not our responsibility. We have no authority in this area. But just like when we did our work in New Mexico, as I explained before, we had some broad, general criteria to work from as to what they were looking at.

Now, as we go into a site-specific area, again we need criteria as to what they are actually looking for. If they want a clean salt, or they want a salt with less than three percent moisture, or just what type of criteria are they looking for.

We have no way of telling that, because we do not know what the controlling factors are.

Q Okay.

Now, you've got some answers on the low-level stuff. We'll leave that for a moment and stay on the high-level waste disposal.

On your answer d., still to the first question, your answer seems to be concerned about the effect of the intrusion—human intrusion into the salt bed in order to [704] form the repository, and you talk about the mechanical, thermal and chemical equilibrium, it being disturbed in the salt bed by the intrusion by the digging out and by the installation of the waste into the salt repository itself. You say, "The effect of natural disturbances on emplaced waste must also be considered."

Now, this brings up a lot of problems. I would like to know what mechanical, thermal and so on effects you see that might cause problems in a long-term repository, and what natural events you are mostly concerned with?

A Your question, as I see it, is in two parts:

What are the natural effects and what are the man-made effects?

Q Precisely.

A It has commonly been stated that, for example, it's been commonly stated that salt is an excellent repository medium. And they use as an example that the salt is some 60 million years old and has never been dissolved by water, yet is very soluble. This we must agree with.

However, we must realize that the salt has not been disturbed by man. It has not had a shaft drilled into it, has not had exploratory holes drilled into it. In the case of the Lyons, Kansas site one of the things which threw the Lyons site out was the inability to discover [705] abandoned drill holes. There were several examples in the immediate vicinity where solution has taken place as a result of these abandoned holes.

This is the type of thing that we were referring to that we must take into consideration if a man is going to go into it. And then the question is you have to have at least two shafts into a repository, one for access and another for ventilation. How many more holes are going to be drilled, or how do you explore a medium without destroying the integrity of the site itself?

Now, insofar as the waste inter-reaction, you're taking an unstable mass of a thermal and chemical nature, adding it into an equilibrium environment and you're getting heat and chemical reactions. And these should be known before you proceed too far down the line.

Also, as you excavate the cavity, you are disturbing the rock mechanics of the area which are involved, in-situ stresses, and so forth, which are involved in the general area.

Q Now, do you feel that as far as resulting mechanical and thermal effects you are worse off in salt than you are if you go down into some other type of rock formation?

A (Witness Trask) I don't think the complete assessment and risk analyses have been made for all the [706] various media, so I don't think we could be prepared to say at this time that salt would be either worse or better than another one.

One of the chemical effects that we're particularly concerned about is the migration of brine from the salt mass toward a heat source. This is a thermal perturbation and it results in a mechanical perturbation as well, because although we don't know all the details yet, it appears that a relatively small amount of salt brine could have a strong mechanical effect on the salt.

There are other media that don't have this problem, they don't have fluids which will migrate towards the heat source. You might have other disadvantages that would have to then be weighed and balanced to see which is the optimum media.

Q What would be your limit as to percentage of brine in the salt that you would feel would be tolerable?

A I think we'd be perfectly happy with one that had zero.

Q Yes, we all agree on that, I guess.

A That's one end point, one end member of the spectrum. Again, I think it's too early to set the exact limit, because we need to do experiments on the rate of migration and the various thermal gradients and detailed studies of this type, with regard to mechanical effect of [707] these fluids.

I think there will be some very low number that will probably prove to be acceptable, but I don't think we can state that number right now.

Q Well, now, you mentioned thermal gradients to be set up by, presumably, the hot wastes that are put in

there and surrounded by salt and so on. And the problem has been mentioned in this proceeding that these thermal gradients might cause an expansion and an upward bowing of the rock above the cavity, which later would be followed by a dropping, and so on.

Do you believe that this type of expansion and contraction is sufficient to degrade the layer of rock strata above the cavity to the point that it might crack through and, shall we say, leak gases?

A I haven't done that analysis, although I have seen the analysis. I think it would have to be looked at critically by people who are knowledgeable in these matters. I've seen analyses which would show that the confining layer above would not be perturbed.

The fact remains we are putting energy underground and energy has the capability of doing work, and there will be some uplift of the whole rock mass. There's no question about that.

The question, I think, that's at issue is: Is [708] this uplift sufficient to cause fracturing? And if it is sufficient to cause fracturing, does this, in turn, allow water and fluids then to migrate downward into the waste?

So there's a whole chain of events that have been suggested as possibilities. I think what is needed is additional analyses. We're not too sure of the mechanical behavior of salt. The statement has often been made that it's plastic and will heal itself quickly. Some experiments indicate at least into some time spans it's rather brittle material and it will fail.

We need to study it further to understand at what scale it will fail by brittle fracture, and at what scale it will fail by plastic flux.

Q Has the USGS not been asked to do analysis of this sort?

A We are concerned primarily with the physical chemistry of the brine-salt system. This is an area where we have considerable expertise. The mechanical proper-

ties are not so much in our area of expertise, and they are being worked on at other laboratories.

Q Is this within the USGS area or outside the USGS area?

A Outside the USGS.

Q I see. Do you know where they're being worked on?

[709] A Sandia Laboratories.

Q They're the ones that are doing that?

A Yes. And Pennsylvania State University too.

Q So you are not intimately involved in this rock study itself, plasticity or otherwise?

A Some of our data on the physical chemistry feeds in to the people that are doing the work on the mechanical properties. So we're in close communication with those laboratories.

Q Okay.

Have you ever had any problems such as this before, a cavity in the ground where you have such thermal gradients causing expansion, and so on? You have not had that experience, in that area, I presume?

A Our experience has been with the geothermal program, which has certain analogies to this problem. Not exactly a duplicate.

Q All right.

Now, you mentioned in your testimony the possibility that the anhydrites might be a better medium for burial than halites. Are there such beds of anhydrites available in this country?

A Yes, there are.

Q Large ones, or many of them, or . . .

A I believe that the beds in New Mexico would be [710] sufficiently thick, provided they met other criteria that we would want to look into.

Q What other criteria?

A Mechanical stability and response to the heat, whether they would fail by brittle fracture, and possibly allow fluids to reach the wastes.

Q Is anybody investigating the anhydrites any further than just the thought that they do have a better thermal characteristic?

A Our laboratories are looking into it, investigating it further.

Q Is that being funded by DOE, or is that something that you're working on of your own interest?

A Yes, that work is being funded by DOE.

Q I see. Dr. DeBuchananne?

A (Witness DeBuchananne) I was just going to add a comment that the Swiss have been working on anhydrites in Europe. How far along they are I'm not sure at this stage. Our people are in contact with them at this time, though.

Q Well, this is a secondary situation at the moment, as I understand the program?

A Yes. Our interest has just been relatively recent. Some of these things came up in our experiments in our laboratory that seemed to show a plus for anhydrites and a negative for the salts.

[711] BY DR. BRIGGS:

Q Could I ask a question about the anhydrite beds? What is the extent of the anyhdrite beds in New Mexico? The thickness, for instance, and other dimensions?

A (Witness DeBuchananne) Well, since we have not been looking at anhydrite under our DOE contract, we cannot say for sure on this. We do not have as much information on that as we do the others. But there is indication that immediately below the site there is a very good potential for an adequately thick bed of anhydrite which would be used.

Q When you say an adequately thick bed, what thickness are you talking about?

A I'm reaching for a number now. But we'll say a few hundred feet thick.

Q You're talking about a few hundred feet thick, rather than a few thousand feet thick, is that correct?

A Correct.

Q And the lateral extent, is it thought that it would be many miles, or . . .

A It appears to be many miles, from other subsurface information we have gleaned from the adjacent areas.

Q Is anhydrite a valuable mineral? Is it in great use?

[712] A Not to my knowledge. It has no really important use at this time.

Q Are there other anhydrite beds in the United States that you know about?

A Almost every salt dome has an anhydrite cap on it, things like this. So there are other anhydrites, yes, sir.

Q I see. Thank you.

BY DR. BUCK:

Q Are these fairly uniform, or are they intruded with a lot of impurities, and so on? Or does this vary?

A (Witness DeBuchananne) Some of them have quite a few impurities. Anhydrite is a salt which can evaporate and as it precipitates out can concentrate.

Q On page 6 of your answer to NRDC questions, I believe you're discussing the deep repository, but you say: "While the past can be used as a guide to the future, the rates of some geologic processes have been known to change dramatically with time so that estimates of future rates must be assigned a higher uncertainty."

What geological processes are you talking about here?

A (Witness Trask) A great many processes. Tectonic movements, for example. We know that sometime ago, 120 million years or so, the continents broke up. So a once stable [713] continent broke up into pieces, with a certain amount of tectonic movement. For that particular area there was a dramatic change in the rate of the geological process.

What we're trying to emphasize in our reply here is that while you can make an estime [*sic*] about what's going to happen in the future based on the past, you must recognize that it is an estimate, that there's no way that a geologist can predict—with any kind of absolute sense—what is going to happen in the future.

Q If we had another continent collision, things would change rather rapidly, I presume.

But when you say the rates of geologic processes, these are over hundreds of thousands of years, is what you're talking about here, not anything that's likely to dramatically push a pluton up in some of these salt beds, or anything of that nature?

A Yes, sir.

BY MR. BRIGGS:

Q Let me go on with that a little bit:

How well do you think one can predict what would happen in the next million years in areas like these areas of salt beds?

A (Witness Trask) I think a million years is pretty much beyond our competence in predicting.

Q Well, how about 100,000 years?

[714] A I might want to make it, say, 30,000 years. This is the limit at which we can date groundwater by the carbon-14 method. So when we find water that's 30,000 years old, we can say with considerable confidence that it would take 30,000 years for that water to reach the biosphere. And we're pretty confident, then, that any waste that would replace them would be in transit at least that long. And there might be events that might change that groundwater flow, but on that short of a time scale we'd be pretty confident in making that prediction.

Q So that's one of the things that you look for, then, age of groundwater using carbon-14, did you say, as the indicator?

A (Witness DeBuchananne) Yes. If I may, or the age of the groundwater deposits, such as a calcite second

side showing that a fault moved and the carbon-14 in that may be on the rock, not in the water itself. But it would indicate that the fault occurred 15,000 years ago, or 35,000 years ago. Up to about 35 or 40 thousand years we can use carbon-14 for a fairly decent reference point. But over that, we have to develop some new techniques which will allow us to age date geologic events.

Q So you don't look at what's in the water, you look at what's in the rock structure?

A We look at both. But it could be actually [715] residual history of the water that passed through this area.

BY DR. BUCK:

Q In your next section, number 3, page 6, you talk about radionuclide transport models and the changing conditions of transport including such effects as ion exchange, precipitation and solution and so on in the medium.

Now, are you saying here that you expect there to be different transport problems with radioactive elements as opposed to the non-radioactive elements? You appear to be making a distinction between radioactive element transportation and non-radioactive transportation, or maybe I'm mis-reading the sentence.

A (Witness DeBuchananne) I think you're reading into the sentence more than we had intended, sir, or we did not state it clearly.

Actually, on the three-dimension groundwater flow, our solute transport flow, we have an awful lot to learn yet. Radionuclides are what we were discussing here, so we used this particular number—or element.

Q You say there was no particular indication there that there was anything particularly different between the radionuclides and—

A Other than there are differences between the radionuclides themselves.

Q Oh, sure. Okay.

Now, you talk in the next paragraph about multiple [716] barriers. Do you agree that this method of depositing radioactive materials in a deep repository in the way in which it's being proposed does present a multiple barrier system to the escape of the radionuclides?

A I think it would depend on which site-specific case you're speaking of, sir. In the case of salt, salt itself is not a multiple barrier. It does not provide any retardation behind the—the KD factor is zero, of radionuclides in brine.

Q Once brine gets in, assuming that you get brine in and it's flowing, then you're saying that the salt itself presents no barrier?

A That's right.

Q Is this the only barrier that is presented by such a repository?

A Well, you still have the time factor of how long it takes the solute transport material to move from the repository area back to the biosphere. There is that time factor which is—

Q That's in the salt?

A In the salt or any medium, right.

Q Now, assuming that you don't get cracking and so on, do you then have the transport media of the rock surrounding the salt? Is that not correct?

A Assuming you—would you re-state the question please?

[717] Q Assuming that the repository remains as it originally was, with no cracking above the repository itself, then once the radionuclides get out into the salt there is the time of transport within the salt itself. Then there would be the further time transport within the rock. Is that correct?

A The overlying strata?

Q That's right.

A Yes.

Q So that in a sense you do have some multiple barrier situation here?

A Yes.

Q Is that correct?

A Yes.

A (Witness Trask) We recognize that as it is planned there are multiple barriers. The waste form itself, as is stated, is a barrier. The mechanical body of rock is a barrier. And the groundwater is also.

DR. BUCK: Mr. Briggs, that's all I have on the deep deposits. Do you have some questions on the low-level wastes, or do you want to go ahead with deep deposits and hold the other until later?

BY MR. BRIGGS:

Q You indicated that once the waste gets into the brine that there is no absorption of the waste by the salt, [718] it just travels with the brine. A statement was made the other day that there is solution of these brine deposits along the boundaries, and that—of the salt deposits along the boundaries—and that they are dissolved away at the rate of about a mile per million years.

Is that a USGS number, that mile per million years?

A (Witness DeBuchananne) I'm not sure that is a USGS number. I think it probably was. At least I'm sure the number was generated on basic data collected by the USGS, that is, the salt contents of the rivers which are draining this area, which is an indication of how fast the salt is being dissolved and carried out of the basin.

Q Do you have any idea how rapidly the salt brine travels from the place where it's converted to a brine—that is, where the salt is dissolved, to the time that it gets into the rivers to drain the areas?

A (Witness Trask) Your question was how long it might take the brine after it . . .

Q What I'm getting at is in these areas where salt is being dissolved away at this rate, like a mile per mil-

lion years, do you have any idea how long it takes for the salt to get—or for the brine to get from the salt into the rivers that drain the areas?

A (Witness DeBuchananne) Usually—I think a mile [719] per million years is based upon where the salt outcrops in the river basins, and so this would be a peripheral, if you will, dissolution of the salt so that it is going immediately into the river.

Q I see.

So it's not the situation where there's an underground river, let's say, that flows past the salt and then finally works its way into the rivers. It's where, in effect, the rivers come in contact with the salt beds?

A Well, where it comes in direct contact or where on the side of the river valley groundwaters are flushing over in a shallow distance back to the facement of the salt.

Q You indicated that solution had taken place as a result of abandoned bore holes at the Lyons, Kansas site. What kinds of information did you get about such pockets? You located pockets like that, did you?

A Well, in this case there was a study made of some four areas where salts had been dissolved and caused collapsing of the overlying strata. And I think the most classic one is where Highway Interstate 70 crosses some of these cavities, and they keep rebuilding the road because it is still sagging. The salt is being removed underground in this case, water is coming up from the underlying formation and getting into the salt and dissolving it, and material is collapsing down around it. And this is [720] continuing on up to the surface and causes a depression.

Q How far below the surface does the salt exist in the Lyons, Kansas site?

A At the Lyons, Kansas site I think in the neighborhood of 900 feet. I'm not positive about that number.

Q And as I understand it, what has happened is holes have been drilled from the surface through the salt into

lower lying areas, and water is coming from those areas through the bore holes, through the salt and back to the surface. Is that right?

A In the past, oil wells were drilled in Kansas and there were no regulations, and, therefore, no records kept as to where these holes were drilled. They were drilled through the salt on into the Arbuckle formation, which is a fairly protected aquifer beneath and on deeper still. No oil was encountered, so the wells were abandoned. They were capped and apparently were not plugged, or any provision made for it. In some cases, the casings were even withdrawn if they could salvage the casings.

So the holes were left and with time erosion has taken its toll, and the formation beneath having much higher hydrostatic head has pushed water up into these salts. It's a circulatory system for the dissolution of the salt adjacent to the bore holes.

[721] Q And this has happened over a relatively few years, few tens of years, I suppose?

A Well, since the turn of the century. Kansas has more modern laws now, and they know. So this is back at the turn of the century when the holes were drilled.

Q How well can bore holes like this be plugged at the present time?

A Actually, the bore hole plugging technique is a relatively new concept. In the past the oil companies have been plugging holes with concrete and saying this is going to stand. They are not speaking in terms of tens of thousands of years. They are just considering the plugging for the immediate expediency.

DOE has contracts out with several different laboratories and companies who are developing bore hole plugging materials which have yet to be demonstrated to be acceptable.

BY DR. BUCK: You're speaking of any size bore hole, now, are you not?

WITNESS DE BUCHANANNE: I'm speaking of any size bore hole, yes, sir.

BY BR. BRIGGS:

Q You indicated that migration of brine has a mechanical effect on the salt and an effect on the mechanical properties of the salt. What kind of information do you have about that now?

[722] A (Mr. Trask) We know salt is wetted by the brine, and when it is wetted there is a greater loss of mechanical strength. We don't know just what percentage content of brine is in the maximum amount of material that is wetted. The nature of salt is it is soluble so it tends to go into solution into the brine. The brines we are talking about are very concentrated, they have more than just sodium and chlorides; they have magnesium, calcium, they are capable of dissolving a large part of the salt. So in effect what you are doing is getting a kind of melting almost of the salt material.

Q As I understand it, the brine is expected to migrate toward the waste?—whether it be fuel rods or glass waste—and then for at least a considerable time it is expected to evaporate there, and to pass off in the ventilation gas, the ventilating air in the mine; is that your understanding?

A There would be an equilibrium of the salt, it probably would be liquid brine, not a steam. The reason for this is the additional components that are present, the ones I mentioned earlier—magnesium, calcium, potassium—what these tend to do is to change the phase equilibria relationships; the fluid that is in equilibrium is brine and not steam. Undoubtedly there would be some steam coming off at the very beginning if you had air pressure if the [723] excavation was open. When it is back filled our results indicate it would probably remain as brine, and remain in the vicinity of the cannister [*sic*]. This is the center of a large part of our concern.

Q Do you have any idea what fraction then would be brine? Presumably you start out with one percent or less brine in the salt, and then I suppose you build up a gradient of brine fraction?

A It is difficult to say what the percent would be at any one time. The time phenomena—the heat source is decaying, so that tendency for the brine to migrate is dropping. Even a small percentage near the cannister [*sic*] might result in loss of strength of the dissolved medium, and perhaps the cannister [*sic*], or the wastes, the fuel rods, might move around, even with a small percentage in the immediate vicinity.

Q Well, what I am interested in is a statement like that that you just made, and what the effect is of the loss in strength, or what the effect is of this material moving around? When you talk about its moving around, are you talking about meters, tens of meters, hundreds of meters? Just what kinds of distances?

A It's the brine you are talking about now?

Q The brine migration, and than [*sic*] the moving of the waste itself when there is brine near it?

[724] A The brine will be moving in from a relatively small area, 30 centimeters, perhaps. How far the waste elements would move, I am not prepared to say. It depends on loss of mechanical strength, the density contrast between the waste and the surrounding medium.

Q Well, you indicated that the brine moves possibly 30 centimeters; so can one say that the loss of strength will be confined to this region of 30 centimeters? Or will it—the loss of strength—be known much further away from the elements?

A It will be closer in; any loss of strength due to migration of brine is toward the waste. This assumes, of course, the holes are plugged so that there is no water coming in from the groundwater system, or from another source. I am talking just about the brine inclusion.

Q Yes.

A Those inclusions will—are strong dessicants; that is, they will tend to pick up moisture if it is around. So ventilating can withdraw moisture from the air that is flowing through. There are indications that will happen.

So there will be a gradual increase in the amount of fluid over that which is in the brine inclusion. It might not be a large volume, but there will be some. There will be a tendency for these things to attract moisture.

Q Well, let us get back to the moving of the waste [725] itself. I understood you to indicate that the movement of the wastes would not be confined to this area of volume of 30 centimeters around the waste, but it might move further than that?

A The waste has its own heat engine with it; it's producing heat all the time, so it's drawing fluids to it as long as the thermal volume keeps above a certain level. So in the immediate vicinity of the waste, there could be a loss of strength over a certain period of time; and during that period of time there conceivably could be movement of the waste.

Q And you are thinking of the cannisters [*sic*] sinking?

A That would be the first possibility. We are not sure of the density of the waste, what it is going to be, and what its density contrasts with the surroundings would be.

Q I see.

Or it might rise?

A It might rise.

Q Well, if you you thought again about distance, could one say that it might move 100 feet, or 100 meters? Or is it just the idea that maybe it will move because of loss of strength?

A Yes. We are not really prepared to say how far it would move. As I have said before, we concentrate on the physical chemistry of these materials and their properties. [726] It is kind of up to someone else to develop the consequences one would gather from these measurements.

BY MR. BUCK:

Q You are not concerned, I take it, that if the heat sources of the caskets, or whatever it is the materials are in, if they are more than a meter away or 30 centimeters

away from the pillars, the mine pillars themselves, that you will not get a loss of strength in those mine pillars· is that correct?

A No. The main concern that has come to mind does not concern the pillars; it concerns the immediate vicinity.

Q The main concern, then, is heating of the materials, shall we say, immediately surrounding the casket and below it so that it moves downwards?

A Possibly downward or possibly upward.

Q Or possibly tipped, something of that nature?

A Yes.

Q So you are thinking of the movement of the waste in bulk in the containment that it is in?

A Yes.

Q I see.

A (Mr. DeBuchananne) This material would be more of a mush than a fluid, surrounding the different cannisters [*sic*].

Q Yes. Thank you.

BY MR. BRIGGS:

[727] Q I believe in your responses you indicated the environmental impacts cannot be realistically assessed unless one had essentially full knowledge of the multi-component physical-chemical system which will develop around the repository. Can you tell us a little bit more of what you mean by this multi-component physical-chemical system?

A (Mr. Trask) Well, when we add new material underground, we have a new system than we had before. I am thinking in terms of primarily physical chemistry. You can characterize the system by the number of chemical components in it.

Now, you might have pure NACL [*sic*] with a little water to start with. That's one very simple system. There may be other natural impurities, such as I mentioned, calcium, magnesium, sulfates; now we have added more components to the natural system and put the waste

down, and we are adding many, many more components. We do not know right now what the oxidation state of the uranium would be and what chemical form it would be in in this complex system. It is not a simple problem any more when you have added the wastes. If uranium is in the form of a chloride, it could be very mobile. If it's in the form of an oxide, it would tend more to stay put.

This is an example of the sort of thing we are saying we ought to know. We ought to know what the form of [728] the uranium would be.

Q What you are concerned with here is the general region around the deposited waste?

A What you call close-in effect.

Q Yes.

You are not concerned about reaction referring to miles away from there?

A No.

Q The Staff has made certain analyses and has arrived at certain environmental impacts in [NUREGs] 0116 and 0216; we will now ask the question: is it reasonable to believe that one can find sites where the fission products will be retained to the extent that has been estimated by the Staff?

A (Mr. DeBuchananne) I think we would generally agree that the concept of geologic disposal is a valid concept. However, we think more in terms of you have the natural situation of geology-hydrology, and all the effects of Mother Nature, so to speak. So you would design the waste to go into the rock, rather than saying, here is a way to put it into the rock.

Am I responding to your question or not, sir?

Q Well, I believe you have both indicated that that [*sic*] NUREG 0116 is an accurate general statement about risks in the response to the question?

A (Mr. Trask) The response there refers to the [729] narrative material that went along with the table.

Q It did not refer to the numbers that came out to be included in the table, is that right?

A (Mr. DeBuchananne) All the table said there was so many thousands, tens of thousands, of curies that would be contained by isolation. It doesn't say what the impacts would be. It's rather difficult to judge the impacts from that type of a table itself.

Q But it also gives some indication of the amount that would be expected to escape from that isolation?

A We would, should I say, question whether we know how much would escape under these other things we have just been discussing.

Q You say there is a considerable uncertainty, then?

A Right.

Q So, as I understand it, you are not prepared to say whether you think those estimates are conservative or not conservative?

A At this stage, I do not think so; no, sir.

Q But, again, did you indicate you believed—well, you indicated you believed the general idea is a good idea, though; the question is: do you believe that one will find places for repositories that will give these low release rates that the Staff estimated?

A Yes, sir, I believe it is possible; but we have not [730] to our satisfaction demonstrated such a site has been located as yet.

Q Now, when a site has been selected, how long do you believe it would take to get the necessary information at that site to determine whether it will meet these criteria that will give the end result the Staff will use in its analyses?

A First we have to know what the criteria are; we have to know what the waste form is. Until we know that, we can only attempt to describe what will happen under a generic sense. That is, we in the Geologic Survey, we can't say unless we know what the waste form is, because this adds other constraints.

Q We have two general waste forms, we have the fuel rods, fuel elements; and we have the glass in which we

place all of our wastes in. We have the general criterion that—I hate to use this word—there shall be negligible escape from this repository over a period of, I suppose, ten thousand years, maybe a hundred thousand years.

Now, with this in mind, how long would you expect it would take to get the information that one needs?

A (Mr. Trask) I think it would be somewhat site-specific as to how long it would take. The barrier afforded by the groundwater system, for example, is fairly well known in some areas, and not so well known in others. So, [731] we would have to gather that information so you could characterize the groundwater flows.

In addition, I think you would have to answer some of these general questions, such as whether or not plutonium was going to move or not in the groundwater system. Some of these things are general, and they apply to any site. It is so hard to pin it down and say how long it is going to take to qualify a site.

Q Well, I suppose you studied the sites in New Mexico more than any of the others; is that right?

Or certainly you studied it for some time?

A (Mr. DeBuchananne) We have not studied the total picture, sir; we have looked at the precautions to isolate six sites as repositories [*sic*]; and we have examined core which has come out of the hole. We have made some general regional groundwater-type investigations; but we have not attempted to evaluate the thermal problems. We are looking at the mechanical stability in the vicinity of the cannisters [*sic*]. We are not prepared to say what that answer is. It is still under investigation.

Q Well, my question was, do you have any idea how long that investigation is likely to take before one can say, we think this is an acceptable site? Is it a matter of two or three years, five years, ten years?

A (Mr. Trask) The New Mexico site is the most [732] assured of any. We could make a judgment in two or three years, assuming no unforeseen problems devel-

oped, then it could move along. You may notice one of the large uncertainties we keep bringing up is the heat source and the effect of heat; and we have suggested to DOD [*sic*] that they might consider the possibility of deliberately storing the wastes above ground for a certain period of time until the heat decays to a rather low level. At that point, one can be much more confident in geology.

Many of the unknowns people worry about seem to go away. So I think one thing is how much conservatism may be estimated in the waste management system along this line, by storing the wastes above ground.

[733] BY DR. BUCK:

Q When you say rather low levels as far as the heat force is concerned, what are you considering the difference in temperature to be between the salt mine and the source?

What do you consider to be a rather low level?

A (Witness Trask) If the temperature of the waste were 100 degrees Centigrade or less, that would be low.

Q 100 degrees Centigrade or less.

How high do you think it could go with some reasonable assurance? Any higher than that?

Is that the limit, a reasonable assurance of maintenance?

A Many of these problems are under investigation, and one might want to go higher later on.

As for now, it would be a conservative approach now.

Q You wouldn't guarantee maintenance of strength above 100 degrees centigrade?

BY MR. BRIGGS:

Q Have you suggested times for storage above ground before placing the waste in the repository?

Have you looked at how long one might have to do this?

A (Witness Trask) Yes.

We are not experts in the form of the waste. I believe just a rough guess, 30 or 40 years might be sufficient, but again—

Q So you are not talking about centuries you are talking [734] about less than—

A It would depend on how long it would get to this criteria, which I suggest was 100 degrees.

Q 100 degrees. I see.

BY MR. BUCK:

Q May I ask just a couple. I would like to go back to the borehole situation for just a moment.

The shaft going down into the mine at Carlsbad, is how large, do you know offhand?

A (Witness DeBuchananne) I do not know what its engineered design is. The other shafts I have been in, such as the Assa mine and so forth, I would say 6-feet square.

Q Now you don't have any guesses as to how we are going to seal this thing at the moment? This is up to DOE?

A DOE. They are talking about backfilling in the repository itself, which we should remember, they can only do about 80 percent. They are going to have about 20 percent porosity, regardless what they use.

Q Now one of the problems that has been mentioned in this sealing of the shaft as protecting against future ice age intrusion and erosion that would be caused by that, do you have any knowledge of what sort of erosion depths the ice age is likely to cause?

[735] A So far as the surface, land surface erosion, no, I do not. I know that there have been some mighty deep valleys scoured by the glaciers in the past.

Q By deep you mean how many feet?

A Several hundred—hundreds of feet.

Now also we know that the Great Lakes, presumably were scoured by glacier effects. We also know the Great

Lakes are still rebounding, uplifting from the effects of this.

Now if such a pressure were applied to the land surface and transmitted down along some sort of a flecking, you are going to have deviations, breaks and fractures which are going to occur.

We do know the pressures of water at the foot of the glacier which are miles thick is reflective of the whole thickness of the glacier, the hydrostatic header.

So you have some tremendous hydrologic pressures applying to the system to be pushed on down into the ground, or what have you.

Q So this becomes a problem not just for the shaft seal, but for the whole strength of the overburden above the repository, right? If that should happen?

A Yes.

Q Thank you.

BY MR. BRIGGS:

Q About the shaft sealing, again, as I understood the [736] problem at Lyons, Kansas, it was that the boreholes had gone down through the mine and down into an aquifer below the mine where the pressures were rather high.

Is it likely that a shaft that goes down to a salt mine will pass through an aquifer before it gets to the mine?

A (Witness DuBuchanne) In the Carlsbad area, there are some minor aquifers overlying the salt beds, yes, sir.

Q Well, let's go a little further here.

Is it likely that if one did not seal the shaft properly, completely, that water from that aquifer could pass down into the salt bed into the mine and dissolve up waste, and then pass through some sort of formation to get to the surface again, or to get to surface waters again, or aquifers above the mine?

A If the plug on a shaft or borehole provided—at the exterior of the plug, provided a pathway for water to

migrate down, it would tend to migrate down and back up again into a gradient procedure to start solution into the mine, the salt itself. And conceivably eventually could get down into the repository itself.

Q I see.

Thank you.

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[PORTIONS OF EPA TESTIMONY
ON
January 26, 1978 *]

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[1032]CHAIRMAN GLASER: And the EPA believes that at least the S-3 tables should reflect or refer to the standards which you've just published, which you've just alluded to?

WITNESS RICHARDSON: Yes. We find it somewhat strange that the Commission should conclude that the impact of nuclear power plants that are going to become operational after 1983 should be much larger than is provided for in regulations which govern NRC and its licensing of these facilities.

CHAIRMAN GLASER: I see.

BY DR. BRIGGS:

Q And your standard for the release of iodine-129 applies to the entire fuel cycle, not just to the reprocessing [1033] plants, but to the waste disposal and any other parts of the fuel cycle?

A (Witness Russell) Not exactly. Waste disposal is not included under those standards. We have a current effort underway.

I'd like to address your previous question a little bit, if I could, Mr. Briggs.

Q Well, excuse me. Let me go back to that previous question.

If the standard does not apply to the waste handling, the waste disposal, and if the iodine must be disposed of

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[* The portions of EPA testimony on January 26, 1978 included Tr. 1032, l. 13 through 1039, l. 11 and 1045, l. 5 through 1048, l. 24. See Certified Index of the Administrative Record in Docket Nos. 79-2110 and 79-2131 at Vol. 24, Doc. No. 9.]

in some waste disposal facility not yet determined but for the purposes of evaluating the impact of the entire fuel cycle facility, what kind of assumptions do you recommend that we made [sic] for the waste part of the system?

A Well, we're working on that currently, and very soon we will have our draft criteria. I'll let Alan address that.

A (Witness Richardson) The assumption that was stated in the promulgation of the standards that apply to planned releases, was that there would be no significant releases from waste disposal.

That's been the position of the Atomic Energy Commission and the NRC all along, and we subscribe to that position. We do not believe that there will be significant [1034] releases from the disposal of waste—I mean significant compared to total releases of material at its point of generation or reprocessing.

Now, as I mentioned before, if you have trouble with that concept then I think you have trouble with the whole problem of radioactive waste. And I don't really believe that it's reasonable to single out iodine-129 and say we're going to assume that waste disposal won't work for iodine-129, and there will be highly significant releases compared to the total quantity available for this particular isotope, but when we turn to all these other unpleasant species such as plutonium and other materials, that there will be no releases of these.

CHAIRMAN GLASER: But isn't the assumption which the Staff made a worst case kind of situation for purposes of these proceedings, and it's a very conservative—or puts a conservative tone on what the Staff has done in its report?

WITNESS RICHARDSON: Mr. Glaser, I would simply reiterate that if the Staff is going to take this conservative position, then it must take a consistent conservative position, and treat all nuclides similarly. And I think that would leave us with a rather meaningless table.

BY DR. BUCK:

Q Isn't that on the assumption that all nuclides [1035] have the same health effects? Do you mean to tell me that all nuclides have equivalent health effects across the board?

A I don't think I've made that implication.

Q Well my point is, you say you want to treat all radionuclides equally, and if you're going to—

A In terms of releases—

Q Let me finish, please, sir.

If you're going to assume that you release one, you have to assume that you release all of them, my question to you is: Is the health effect, cumulative, of iodine equal to the cumulative health effect if one was to release all of the plutonium?

A I'm not sure where your line of questioning is leading, but I think the answer is no.

Q Well, never mind where my question is leading. I'd like you to answer my question, sir.

A I think I have. No. The impact is not the same.

Q All right. Well, then, is it not possible to treat one isotope slightly differently from another, or even a great deal differently from another?

A I think one would have to have a very good reason for doing so, and I have not seen such a reason.

Q How about the emission of radium from a coal plant? Is that treated the same way?

A I'm not sure that that's the subject of this [1036] hearing.

Q Well, I'm asking you. This is a radioactive isotope.

A Yes.

Q You want to treat all radioactive isotopes the same. Now, I'm asking you: Is that treated the same way?

A It's not treated at all in this hearing, so I'm not sure I can answer the question.

CHAIRMAN GLASER: Let me see if we can put this matter if [sic] proper perspective.

I think we want to find out what would be the basis for your statement that all of the radioactive isotopes ought to be released, and whether or not that's a reasonable suggestion.

Dr. Buck is asking you about another particular radioactive isotope, and he wants to see whether or not that is something that we can weigh in in [*sic*] testing your assumption. That's what he's asking you about.

WITNESS RICHARDSON: I see. I'm sorry, Dr. Buck. I think I misunderstood—

BY DR. BUCK:

Q Well, I am trying to get a point across, and if you would stop being quite as persistent in what you're insisting on doing here, we might get somewhere.

[1037] A Well, you have made the assumption, I believe, that I have suggested that the Staff ought to assume 100 percent release of all radionuclides.

Q No.

A I think that's a reductio ad absurdum, which—I was pointing out just that—

CHAIRMAN GLASER: Excuse me. You said that the Staff assumptions ought to be applied consistently. And if we do that, then all the radioactive isotopes ought to be released, just like they've released iodine.

WITNESS RICHARDSON: I think a logical conclusion from that statement is that iodine ought to be assumed to be retained along with all the other radionuclides.

CHAIRMAN GLASER: Well, they released it because they're, as they say, being conservative, and they've calculated the health effects of doing that. And your argument is that they should not have done that.

WITNESS RICHARDSON: That's correct.

CHAIRMAN GLASER: Or if they do do it, they ought to release all the others.

WITNESS RICHARDSON: I'm simply pointing out, if they make this conservative assumption for iodine-129 they're logically driven to make the same assumption for

other radionuclides. And that is a fairly ridiculous situation which we would not endorse.

[1038] BY DR. BUCK:

Q Why? Why? Why is that conclusion ridiculous?

A Because obviously these materials are not going to be released, or we wouldn't have nuclear power.

CHAIRMAN GLASER: If they were retained, you'd have different health effects than those calculated by the Staff, wouldn't you? We'd have a different situation, wouldn't we, different values in the S-3 table, if iodine is retained and stored and treated as the others?

WITNESS RICHARDSON: Yes, we would. We'd have lower values.

CHAIRMAN GLASER: We'd have lower values.

Would that be more conservative or less conservative?

WITNESS RICHARDSON: That would be more realistic, and it would reflect existing regulations.

CHAIRMAN GLASER: Well, then, would it be more conservative or less conservative than the values which Staff has come up with, if you treated iodine that way?

WITNESS RICHARDSON: My understanding of the purpose of Table S-3—

CHAIRMAN GLASER: Answer my question, then you can explain it. You have a habit of not responding to questions put to you directly. It's most disconcerting.

WITNESS RICHARDSON: It would be—I can't [1039] answer the question, because the word "conservative" has very many connotations.

CHAIRMAN GLASER: Well, you answer it as you understand how the Staff has used the word "conservative."

WITNESS RICHARDSON: It would result—if they made the assumption that the existing regulations are going to be followed, the resulting value would be smaller.

CHAIRMAN GLASER: Well, would that be a worse effect than the Staff has shown, or a better effect?

WITNESS RICHARDSON: It would be a lesser effect.

CHAIRMAN GLASER: All right.

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[1045] Q Well, now, the doses and the health effects are not included in Table S-3 at the present time. They are in the record as we have it as supplementary information, if you wish, in the same way that economics is. And the suggestion is that these matters should be considered in the individual licensing proceedings along with the other radiation impacts.

In your view is this a reasonable thing to do, and then along with that, these various time factors be included in the discussion in the individual licensing proceedings?

A I don't think we really have any alternative, Mr. Briggs. As I understand it, this hearing is not an environmental impact—a NEPA process. It's merely a hearing—I shouldn't say "merely," it's a difficult job—it's a hearing which has the purpose of laying out what the impacts are. The decision about the acceptability of those impacts versus alternative courses of action is left to the full NEPA process which takes place when an EIS is prepared for an individual power station.

[1046] Q And you find that to be an acceptable procedure?

A I find it not only to be acceptable, but I think the only one open to us.

BY DR. BUCK:

Q I am a little—does anyone wish to add anything to that/ [*sic*]

A (Witness Ellett) Only that I think this makes it very important that the information available for this assessment for the individual plant be laid down in a clear form; and that means expressing it in terms of health effects over various periods of time. I find at least the draft or proposed versions of S-3 very disconcerting, and it is impossible to get much idea of what the health effects are from the numbers generated.

I have talked to people less knowledgeable than myself in the general public that feel that no assessment for risk has been made of nuclear power plants by NRC, and the reason is the information is totally indecipherable. And if it's indecipherable to me, I think it's indecipherable to the public.

EPA has followed a practice, and though they have been criticized for it, I think our leaders have been quite correct in saying, "estimate health effects in terms people can understand." 600 man/rem [*sic*] or person/rem [*sic*] means very little to a layman, and unless you know what organs they are talking [1047] about, which are never specified in the table, they mean very little to the experts.

I think these things have to be laid out so that people can make rational choices, and this is impossible on the basis of S-3 as I see it now.

Q Well, don't we have to put S-3 into perspective here? S-3. S-3 is the table—and I agree that some of your criticisms of the clarity and the connection of the narrative of the table and all that sort of thing are rather difficult to follow and come up with something; but let's put this into perspective.

This is one section of the entire cycle, and the largest amount by far is radioactivity that is emitted to the atmosphere and that sort of thing probably comes from the reactors themselves. And what we are concerned with here is how these things fit into the overall radiation effects, the overall effect; and all we are talking about in S-3 is that particular part of that cycle.

And you have to add that part of the cycle into the cost-benefit effect of each individual reactor or each individual process that you are going to license. And do you see a difficulty of adding the data, the results, of S-3 into a licensing hearing, and adding that into the effects of that particular plant that you are licensing?

A Yes, sir, I do. I disagree with the basic assumption [1048] that the amounts of activity are small compared to what happens from reactor releases. Our analysis

shows the health effects of the reprocessing is important for a much larger number of health effects; and I think it's something that should be swept under—if you will—I don't think it's a small part. It's a part that hasn't been analyzed effectively in the past.

Q Isn't that what we are in the process of doing? Isn't that what S-3 is trying to do, and this is why we are holding this hearing now, because reprocessing and disposal were said by the court not to be up to snuff?

A Yes, sir, but more than that, I think we are trying to decide if Table S-3—you are trying to decide with what testimony we can give whether S-3 is an effective and accurate way of doing this.

I submit that it is incomplete.

Q That may be so. The court has actually accepted this table except for these two items, and this is what we are concerned with at the moment; and all we are trying to do, I think, here—what I am trying to do is put this thing into perspective: the fact that you do get a cost-benefit analysis, you do get an analysis of the health effect, adding in a proportion of the fuel cycle effect to each plant that you license.

* * * *

[NRDC QUESTIONS FOR EPA (November 18, 1977) AND EPA RESPONSES (docketed March 20, 1978)*]

Below are the questions that participant Natural Resources Defense Council requests the Hearing Board to propound to the Environmental Protection Agency. Although the NRC staff in its transmittal of the EPA statement requested the Hearing Board to consider the EPA comments as filed on December 2, NRDC suggests these questions now and asks the Hearing Board to propound them to EPA on November 21. In this way, the original schedule will be more closely adhered to and there will be an opportunity to ask follow-up questions. Under the NRC staff's proposal an opportunity to ask follow-up questions would be foreclosed.

1. In its statement, EPA concludes that, ". . . this rulemaking process must also conform to the requirements of the NEPA process." (at 1) In the opinion of EPA, does the proposed Table S-3 adequately represent the possible environmental impacts of the nuclear fuel cycle as required by NEPA? If not, explain how the proposed Table and rule should be modified so that it will satisfy fully the requirements of NEPA.

2. In its statement, EPA ". . . urge[s] the NRC to adopt a method of analysis which results in a realistic total environmental impact." (at 6)

   (a) In the proposed Table S-3, the NRC staff lists the environmental impacts of radioactive releases in terms of curies. Does EPA believe that

[* See Certified Index of the Administrative Record in Docket Nos. 79-2110 and 79-2131 at Vol. 18, Doc. No. 24 and Vol. 26, Doc. No. 22, respectively.]

the curie is an appropriate or a "realistic" measure of environmental impact for an environmental impact statement? If, not what unit should be used and what is the relationship of that unit to environmental dose comitment [*sic*], if any?

(b) Does EPA think that a table revealing environmental impacts of the uranium fuel cycle for only one-year's operation of a nuclear power plant satisfies the requirements of NEPA or provides a "realistic" assessment of environmental impact? If not, why?

(c) Does EPA believe that the cumulative environmental impacts of the uranium fuel cycle should be presented in the environmental impact statements for individual nuclear power plants in order to present a "realistic" analysis of environmental impact? If so, how should those cumulative impacts be presented?

(d) Does EPA think that a numerical table like the proposed Table S-3 can *in principle* fulfill the requirements of NEPA and provide a "realistic" appraisal of environmental impact, or should a narrative describing the underlying assumptions and uncertainties in the numbers also be presented? Also, are there environmental impacts that are difficult to quantify that should be discussed in an accompanying narrative?

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE HEARING BOARD

Docket No. RM-50-3

IN THE MATTER OF

URANIUM FUEL IMPACTS
FROM SPENT FUEL REPROCESSING AND
RADIOACTIVE WASTE

EPA RESPONSES TO PROPOSED QUESTIONS OF NOVEMBER 18, 1977, BY THE NATURAL RESOURCES DEFENSE COUNCIL, INC.

Submitted by:

Office of Radiation Programs
U.S. Environmental Protection Agency
Washington, D.C. 20460

The following are the answers to questions directed to the U.S. Environmental Protection Agency (EPA) by the Natural Resources Defense Council, Inc.

1. EPA does not believe that the Proposed Table S-3 adequately represents the anticipated environmental impacts of the nuclear fuel cycle as required by NEPA. We have enumerated what is required in Dr. Rowe's testimony of January 16, 1978, and in further staff testimony on January 26, 1978. Further clarification will be found in the response to the next question.

2. (a) EPA does not believe that curies are an appropriate measure of impact. The impact is on health in the form of cancers and genetic effects, and the health impact is best related to environmental dose commitments through the use of best assumed values for these radiation risks.

   (b) We do not believe that the impact of one year of operation satisfies the requirements of NEPA, because the EIS and the licensing decision are for permission to operate a plant for its anticipated lifetime, not for one year. Moreover, the persistence of radioactive materials in the biosphere must also be considered; this is much larger than either one year or the plant lifetime.

   (c) If, by "cumulative environmental impact," the question refers not to the environmental dose commitments attributable to a single facility, but to those resulting from the entire uranium fuel cycle at the time of proposing a new power plant, we do not believe that calculation of cumulative impact is necessary. In order to justify such a requirement for calculation of the entire industry's cumulative impact it would be necessary to show an effect of cumulative impact which is greater than proportional to that due to individ-

ual facilities. We know of no such phenomenon associated with radioactive effluents from nuclear power.

(d) No, qualitative material is clearly required when presenting impacts with as many uncertainties as in this case. A purely numerical table is, in fact, an implication of far greater certainty than is warranted by the facts. Clearly, for the time spans involved in presenting the impacts of certain radioactive effluents, there are environmental impacts difficult to quantify that require accompanying narrative.

3. Also as requested by the Hearing Board, we have listed publications and references on Calculations of Environmental Dose Commitments.

(a) NCRP Report No. 44, "Krypton-85 in the Atmosphere," July 1, 1975.

(b) G.G. Killough, "A Diffusion—Type Model of the Global Carbon Cycle for the Estimation of Dose to the World Population from Releases of Carbon-14 to the Atmosphere," ORNL-5269. (May, 1977)

(c) "Sources and Effects of Ionizing Radiation," United Nations Scientific Committee on the Effects of Atomic Radiation, 1977 report to the General Assembly, with annexes, New York, 1977.

(d) "The predicted radiation exposure of the population of the European Community resulting from discharges of krypton-85, tritium, carbon-14, and iodine-129." G.N. Kelly, J.A. Jones, P.M. Bryant, and F. Morley. Commission of the European Communities, Luxembourg, Sept. 1975, Doc. V/2676/75.

(e) D. Beninson, "Population Doses Resulting from Radionuclides of Worldwide Distribution" in

Population Dose Evaluation for Man and His Environment, International Atomic Energy Agency, Vienna, 1974, IAEA-SM-184.

(f) "Environmental Radiation Dose Commitment: An Application to the Nuclear Power Industry," U.S. Environmental Protection Agency, Report EPA-520/4-73-002 (February, 1974).

Enclosed is a copy of the *Federal Register* Notice on the "Environmental Radiation Protection Standards for Nuclear Power Operations".

[PORTION OF NRDC CLOSING STATEMENT BEFORE THE HEARING BOARD (June 26, 1978)*]

EXHIBIT A

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

HEARING BOARD

Michael L. Glaser, Chairman
Dr. John H. Buck
R. Beecher Briggs

Docket No. RM 50-3

IN THE MATTER OF

AMENDMENT OF 10 CFR PART 51
LICENSING OF PRODUCTION AND
UTILIZATION FACILITIES

(Environmental Effects of the
Uranium Fuel Cycle)

THE CLOSING STATEMENT OF THE NATURAL RESOURCES DEFENSE COUNCIL

Submitted by

Helene Linker
Terry R. Lash

June 26, 1978

[* The portion of the NRDC Closing Statement before the Hearing Board consists of pages 23-49. See Certified Index of the Administrative Record in Docket Nos. 79-2110 and 79-2131 at Vol. 31, Doc. No. 2.]

* * * *

V. THE RECORD IN THIS RE-OPENED HEARING DEMONSTRATES THAT THE INTERIM RULE IS WHOLLY INADEQUATE

The record in the re-opened proceeding demonstrates clearly that Table S-3 fails to meet the requirements of NEPA to disclose fully and in understandable terms the environmental impacts of waste management and disposal. As a result of a number of fundamental deficiencies in Table S-3, the U.S. Environmental Protection Agency (EPA), the federal agency with primary responsibility for setting generally applicable radiation protection standards and for determining the adequacy of environmental impact statements, found the Table wholly inadequate:

> "EPA does not believe that the proposed Table S-3 adequately represents the anticipated environmental impacts of the nuclear fuel cycle as required by NEPA." [8]

The head of the EPA's Office of Radiation Programs reiterated this concern before the Hearing Board:

> "[W]e believe Table S-3 in its present form represents neither an adequate nor conservative assessment of the environmental impacts of planned release for the balance of the cycle."
>
> Tr. at 75.[9]

The major deficiencies in the interim rule can be placed generally into two distinct, but partially overlapping, categories, according to whether they pertain to issues that cannot or can be addressed adequately within

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[8] EPA Responses to NRDC's Proposed Questions of November 18, 1977, at 1, (undated).

[9] References to Transcript (Tr) are to the transcript of the oral portion of this proceeding conducted before the Hearing Board, commencing Jan. 16, 1978.

the conceptual confines of a numerical table. An example of the first category—that is, an issue that by its very nature cannot be described adequately in a numerical table—is the substantial uncertainty surrounding the degree of isolation achievable by the most likely means for disposing of wastes. For instance, the state of geological knowledge does not permit a reliable quantification of potential radioactive releases from a deep, underground high-level waste repository during the next million years or so. There are also important uncertainties surrounding the actual implementation of a satisfactory waste management and disposal system.

In the second category are such issues as quantitative estimates of the number of deaths from cancer induced by environmental releases of radioactive wastes, and quantitative estimates of some cumulative impacts. While these latter issues are omitted from Table S-3, they could be included in principle. The uncertainty, the range of responsible scientific opinion and the methodology supporting these estimates, however, have to be included in a narrative accompanying them.

The evidence introduced in this proceeding demonstrates clearly that Table S-3 is deficient in both categories. Because the record is so voluminous, in this closing statement we only highlight the evidence establishing the major deficiencies in the rule as now proposed. The listing of unnecessarily repetitive evidence is avoided.

A. *There Are Several Major Uncertainties And Issues That Cannot Be Revealed Adequately In A Chart Form*

The evidence has established that the numerical chart format of Table S-3 fails to disclose fully the environmental analysis and impacts of the backend of the nuclear fuel cycle. This deficiency is due to the inability of a chart to disclose (1) the many uncertainties that exist with respect to the environmental impacts and risks

associated with waste management and disposal, (2) conflicting scientific views about the magnitude and significance of potential impacts, (3) the difficult or impossible to quantify effects, (4) the underlying assumptions and methodologies used to estimate quantifiable impacts, and (5) the failures associated with past attempts to manage and dispose of radioactive wastes. Lacking the ability to reflect these aspects of a full analysis, Table S-3 is unintelligible, certainly to the lay reader, and even to the experts in the nuclear field.

The basic flaw of the interim rule—that is, its failure to include a narrative—was clearly stated by the EPA in its written responses to questions posed by NRDC:

> Q. "Does EPA think that a numerical table like the proposed Table S-3 can *in principle* fulfill the requirements of NEPA and provide a "realistic" appraisal of environmental impact, or should a narrative describing the underlying assumptions and uncertainties in the numbers also be presented? Also, are there environmental impacts that are difficult to quantify that should be discussed in an accompanying narrative?" [10]
>
> A. "No, qualitative material is clearly required when presenting impacts with as many uncertainties as in this case. A purely numerical table is, in fact, an implication of far greater certainty than is warranted by the facts. Clearly, for the time spans involved in presenting the impacts of certain radioactive effluents, there are environmental impacts difficult to quantify that require accompanying narrative." [11]

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[10] NRDC Proposed Questions to the EPA, #2(d) at 2 (November 18, 1977.)

[11] EPA Response to NRDC's Proposed Questions of November 18, 1977, #2(d) at 1, (undated).

The U.S. Geological Survey (USGS), in response to questioning, also characterized the chart form of Table S-3 as inadequate.

Q. ". . . In light of the complexities in assessing the degree of uncertainty and risk, does USGS believe that Table S-3 by itself adequately alerts potential readers of EIS's on individual reactors, including lay-people, to those uncertainties and their possible significance? If not, how would USGS supplement Table S-3 so that it adequately informed the public about the uncertainties surrounding the disposal of future high-level radioactive wastes in geological formations? In particular, would USGS favor a narrative accompanying the table to explain, among other things, the uncertainties in predictions of the geological behavior of radioactive wastes?" [12]

A. "Table S-3 by itself clearly does not convey an appreciation of the risks involved in geologic disposal of high-level radioactive wastes or the uncertainties involved in determining such risks. The uncertainties involved in predicting the geological behavior of radioactive wastes and of a repository are probably best conveyed by narrative material, but whether such material should be incorporated in Federal regulations is a legal question that the USGS is not qualified to answer." [13]

Similarly, Dr. Lash, a witness for NRDC, stressed the inability of a numerical chart to provide the necessary disclosure:

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[12] NRDC's Proposed Follow-up Questions to the USGS, #1 at 1, December 16, 1977.

[13] U.S.G.S. Response to NRDC's Follow-up Questions of December 16, 1977, #1 at 1, (undated).

> "One of NRDC's major objections to the use of Table S-3 without an accompanying narrative is that a single numerical table, standing by itself, provides no indication of the massive uncertainties and assumptions in the calculations made to derive the reported numbers. For instance, lack of experience with satisfactory practices for long-term disposal of high-level waste, results in two fundamental uncertainties: (1) the uncertainty as to the actual feasibility of implementing a safe operational waste disposal system, and (2) the uncertainty in our ability to predict the behavior of wastes once emplaced in a geologic repository."
>
> [Lash Testimony at 7].[14]

Lastly, we note that a recent special task force that was established by the NRC to review the issue of radioactive waste management and to make recommendations of goals in establishing an effective waste management system, issued its report after the closing of the evidence in this proceeding. One of the authors of this report is Dr. Bishop, who, according to NRC counsel in this proceeding, ". . . is sort of our overall guy [in waste management] . . ." Tr. at 125. One of the task force's recommendations for a goal during the time period of active use of nuclear power is,

> "The existence of scientific, technological, and organization uncertainties in any waste management system shall be made explicit, along with the logic and procedures used to address them." [15]

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[14] Written testimony of Dr. Terry R. Lash, Submitted on Behalf of NRDC, October 3, 1977. Hereinafter "Lash Testimony."

[15] Bishop, *et al.*, Office of Nuclear Material Safety and Safeguards, UNSRC, *Proposed Goals for Radioactive Waste Management*, NUREG-0300, at 6 (May 1978). [hereinafter "Goals Report."]

Thus, in this proceeding, by suggesting that the interim Table S-3, which is incapable of disclosing these uncertainties, can suffice as a final rule, the NRC staff seems to be ignoring this task force's fundamental and crucial advice—inclusion of an evaluation of uncertainties in the fuel cycle rule.

1. *There are Large Nonquantifiable Technological and Scientific Uncertainties that can be Presented Adequately Only in Narrative Form.*

The magnitude and extent of the uncertainties concerning the environmental impacts of waste management and disposal are substantial. The NRC staff itself acknowledged repeatedly in this proceeding that there are uncertainties and scientific disputes about the degree of isolation of radioactive wastes achievable in practice and about the effects of radionuclides released into the human environment. As two important examples of this problem, we cite below some of the evidence on the massive uncertainties in predicting the behavior of high-level radioactive wastes deposited in a deep geological formation, and of the uncertainties in the magnitude of deleterious health effects that may be caused by waste management and disposal operations. A narrative accompanying an improved Table S-3 would have to consider significant uncertainties in all phases of the waste management and disposal system to be adequate, however.

With respect to the uncertainties of geological disposal the NRC staff has admitted:

> "Past work does not, however, fully cover the risk situations that should be explored. Representative studies have been done with varying degrees of depth and sophistication, but there are still uncertainties in areas such as the effect of waste presence on repository stability; the probabilities and consequences of intrusive acts by humans; the validity of data used in modeling studies; the design and regulatory

> actions needed to minimize possibilities of repository failure; projection of future societal habits and demography, and finally, the relative importance of various initiating events."
>
> NUREG-0116, at 4-94.

Again in response to a question, the NRC staff stated that there are "considerable uncertainties in the long term" pertaining to the disposal of high level waste and spent fuel.[16] Similarly, during the course of the oral portion of this proceeding, the staff acknowledged that there are ". . . considerable remaining uncertainties." Tr. at 534.

The USGS, the most knowledgeable federal agency on technical geological matters, also emphasized the existing uncertainties involved in assessing the capability of geological formations to isolate high- and low-level wastes. *See generally*—Tr. at 704-708; Tr at 712-736.[17] George DeBuchananne, chief of the Office of Radiohydrology of the USGS, noted that there is "considerable uncertainty" about how much radioactive waste might escape from a repository. Tr. at 729. The USGS also stated that NUREG-0116 ". . . indicated many gaps in knowledge suggesting that in general the present uncertainties of predictive modeling of waste behavior are high."[18] Due

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[16] NRC Staff Responses to NRDC's Proposed Questions of November 18, 1977, #26(a) at 7-71 (December 2, 1977).

[17] *See also* Statement of George D. Debuchananne, Chief, Office of Radiohydrology, Water Resources Division, U.S. Geological Survey, on Geologic Storage and Disposal of Radioactive Wastes, before the Subcommittee on Nuclear Regulation of the Senate Committee on Environment and Public Works, at 8-11, April 4, 1978. This statement was entered into the record of the proceeding May 25, 1978.

[18] USGS Responses to NRDC's Questions of November 18, 1977, #2(a) at 5 (undated).

to these uncertainties, particularly with respect to the mechanical behavior of salt formations, Dr. DeBuchananne called for needed "additional analyses". Tr. at 708.

More recently, in a publication that has been entered into the record of this proceeding, the USGS reiterated that there are significant uncertainties in knowledge about geological disposal of high-level wastes: "[S]ome key geologic questions are unanswered, and answers are needed before the risk associated with geologic containment can be confidently predicted.[19] The authors of this USGS paper also stated that ". . . given the current state of our knowledge, the uncertainties associated with hot wastes that interact chemically and mechanically with the rock and fluid system appear very high." [20] Compounding the uncertainty in existing models that predict the consequences of host rock-waste interactions if [*sic*] ". . . the lack of a method for determining the future rates of many [geological] events and processes . . . ." [21]

The scope of uncertainty and the need for additional analysis was also stressed in a statement by Emilio E. Varanini, a Commissioner of the California Energy Resources Conservation and Development Commission, a participant in this proceeding:

> "The statement is commonly made by those promoting the geologic disposal program that there is general agreement among technical groups that geologic disposal is acceptable. After spending months pouring over the reports of these technical groups, it is clear that the groups have *not* said that geologic disposal of waste is safe and acceptable now, but rather that it is a concept which looks promising,

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[19] *Geologic Disposal of High-Level Radioactive Wastes—Earth-Science Perspectives*, Geological Survey Circular 779 at 3 (1978) [hereinafter USGS Circular].

[20] *Id.* at 6.

[21] *Id.* at 11.

> does not have obvious disqualifying features, and should be pursued. It is equally clear from this reading of the reports, however, that we do not know as a matter of scientific evidence and experimentation whether the concept of geologic disposal will in fact work or not. There is simply not enough information developed to answer the question." [22]

Most recently, these opinions concerning the large degree of uncertainty in our ability to predict the fate of high-level wastes deposited deep underground are reinforced by a recent report to the EPA by a special panel of earth scientists. This panel found that even though some of the radionuclide transport models being applied to the environmental assessment of the waste disposal problem represent the state of the art of engineering capability, there are still substantial uncertainties. These uncertainties in the results from radionuclide transport models are primarily due to not knowing the appropriate values for many key parameters in the models. Indeed, the situation is sufficiently complex and difficult that "[I]t is not [even] possible in general, to delineate unambiguously the importance of the uncertainty associated with [individual parameters], for example, the source term." [23]

In addition to the uncertainties associated with the transport models, the panel believes that there are "extreme numerical uncertainties attached to most [other factors that may lead to disruption of a waste reposi-

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[22] Statement of Emilio Varanini Before the Hearings of the Subcommittee on Nuclear Regulation Senate Committee on Environment and Public Works on Nuclear Waste Management, at 5, (April 4, 1978). This statement was incorporated into the record of this proceeding May 25, 1978.

[23] Report of Ad Hoc Panel of Earth Scientists, The State of Geological Knowledge Regarding Potential Transport of High-Level Radioactive Waste From Deep Continental Repositories, EPA/520/4-78-004, at 32 (June 1978) [hereinafter Ad Hoc Panel Report].

tory]." [24] For instance, "there are very few bases for judgment" about the effect of building the repository of ionic transport rates characteristic of the intact geological formation." [25] Also, there is "uncertainty about the long-term effectiveness of having sealed shafts in bedrock." [26] Furthermore, the panel doubts that the possibility of man intrud- [*sic*] on the repository in the future "is amenable to meaningful probability analysis." [27] The panel also stated that but for very few areas we cannot have "any confidence [even] in orders-of-magnitude estimates of risk probabilities." [28]

According to this panel:

> "There is also no basis for predicting where, or when, . . . uplifts may occur on the stable shield of the continent. The point is that there is a finite but very low probability that a repository buried at a depth of 0.5 km almost anywhere might, within a relatively short time, unpredictably reappear at the earth's surface. How can one make an orders-of-magnitude conjecture concerning these probabilities is beyond the Panel's ability to resolve." [29]

Despite these pervasive uncertainties about the effectiveness of geological disposal of radioactive wastes that have been amply established by the record in this proceeding, and even acknowledged by the NRC staff, herein, the staff persists in asserting that a single numerical value in Table S-3 can give an adequate reflection of potential impacts. Incredibly, despite these uncertainties and on the basis of insufficient information, the staff in-

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[24] *Id.* at 35.

[25] *Id.*

[26] *Id.*

[27] *Id.*

[28] *Id.* at 37.

[29] *Id.* at 40.

explicably predicts "that there is a negligible long-term risk of failure of the [high-level waste] repository". NUREG-0116 at 2-18. The specific judgment, in fact, is that there would be absolutely no release of radioactivity to the human environment from the wastes in a geological repository after operations in the repository ceased. NUREG-0116 at 2-10.[30] Nowhere does the Table S-3 disclose the uncertainties inherent in this calculation or even the assumption the staff made in reaching this remarkably low estimate of future impacts.

Thus, the urgings of the USGS that "[u]ncertainties need to be faced candidly in public discussions of radioactive waste disposal," [31] as well as the conclusion of the panel of earth scientists reporting to EPA that "[I]t is of paramount importance that the analyst present unambiguous estimates of uncertainty [in forecasts of radionuclide transport] so that decision-makers are not misled into believing that such forecasts are independent of parameter uncertainty," [32] are ignored.

The NRC staff evidently is content to bury its inadequate discussion of geological uncertainties within background reports. NUREG-0216 at 3-7. If the NRC staff's view prevails, someone who reads an EIS on an individual nuclear power reactor containing Table S-3 will not be alerted to even the uncertainties admitted by the NRC staff, let alone the uncertainties identified by other governmental agencies and other experts. Such an approach is clearly deficient, because the weight to attach to the NRC's judgments cannot be reliably determined by the public without considering the degree of uncertainty underlying those judgments.

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[30] See also NRC Staff Responses to NRDC Questions of November 18, 1977, #22 at 7-65. (December 2, 1977).

[31] USGS Circular 779, *supra* n.19 at 12.

[32] Ad Hoc Panel Report *supra* n.23 at 45.

In addition to the uncertainties concerning deep geologic disposal technology, there are ample uncertainties and diverse views regarding the adverse health effects exposure to radiation will have. In the only NRC staff analysis of ill-health effects prepared for this proceeding, Appendix C of NUREG-0216, there is no serious mention of any of these uncertainties in prediction. The opinions of several experts in this proceeding, however, differed substantially from the NRC staff's positions on many particular aspects of the calculations in Appendix C. See discussion *infra* at 44-49. In many cases we believe that these outside opinions are correct and that the analysis of the NRC staff is wrong. As set forth below, the evidence establishes that the experts from the EPA and Drs. Pohl and Gofman, Sierra Club witnesses, and Tamplin and Cochran, NRDC witnesses, in this proceeding, all strongly disagree with major parts of the NRC staff's assessment of radiological impacts on man contained in Appendix C. Even if, contrary to our view, the NRC staff remains unconvinced by these experts' view, at a minimum the NRC is obligated to inform the readers of only the EIS's on individual power reactors that there is a diversity of responsible scientific opinion on these matters and to explain to them why the NRC has rejected these other scientific viewpoints. Absent such a discussion, decision-makers and laypeople reading the EIS's will be misled into believing that these alternative opinions about the production of deleterious health effects do not exist. The only acceptable way to handle this type of situation is to have a narrative discussion accompany the table.

2. *There are Important Unquantifiable Socio-Political Uncertainties That Must be Included in the Assessment of Environmental Impacts.*

As one student of waste management and disposal recently observed,

> "Every phase of nuclear energy development, from mining of the raw material to the disposal of its wastes, entails an almost unprecedented combination of technical issues, all of which contain high social content . . ." [33]

The important "Goals Report" also addressed the issue of unquantifiable socio-political aspects of waste management and disposal. The task force recommended as a goal that,

> *Values not easily quantifiable shall be actively considered in the decision-making process.*[34]

The task force went on to explain the reason for this goal as follows:

> "While quantifiable factors such as cancer deaths, environmental pollution, land commitment, and others are of central importance in evaluating waste management systems, they do not exhaust the range of considerations or impacts of the implemented system. Other often nonquantifiable impacts on the societal fabric require understanding and elucidation. Moral and ethical issues can no longer be waved aside simply because they cannot be reduced to an equation. In the decision-making process these nonquantifiable but important considerations must be addressed and given whatever weight their significance demands.
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> [W]aste management programs, like all human activities, involve both technical hardware and human organizations. Shortcomings in either will affect how

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[33] I. Hoos, "Assessment of Methodologies for Radioactive Waste Management" in Office of Nuclear Material Safety and Safeguards, USNRC, ***Essays on Issues Relevant to the Regulation of Radioactive Waste Management***, NUREG-0412 at 43 (May 1978).

[34] Goals Report *supra* n.15 at 5.

well a program is implemented. This suggests that as much attention should be paid to management and institutional considerations as to technological ones . . ." [35]

Dr. Todd LaPorte, an expert in the socio-political effects of radioactive waste management, noted the inadequacy of Table S-3 in dealing with the "human" aspects of the waste management and disposal system.

> "The absence of large-scale operational information [in Table S-3] has a significant political effect. It is the characteristic of the apparently rapidly increasing scale of operations and concomitant increasing potential for error that is the basis for considerable public uneasiness. In the absence of information about the scale of operations, the public and its leaders perceive that a number of critical issues have been left in a state of great uncertainty . . . that could alter the cost calculations of nuclear energy . . ."
>
> [La Porte Testimony at 5.] [36]

Similarly, Dr. Lash stressed the need for a consideration of socio-political factors for a realistic appraisal of waste management impacts:

> "The basic point here is that the Task Force's failure to consider local politics invalidates its implicit judgment that the assumed technologies (in this case, a high-level waste repository in an acceptable bedded salt formation) will be available and that it is inappropriate to analyze the impacts under the assumption that the technologies will not materialize. (NUREG-0216, page 3-117) The importance

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[35] *Id.* at 5, 20.

[36] Written Testimony of Dr. Todd LaPorte Submitted on Behalf of NRDC (October 3, 1977).

of these "institutional" barriers to successful waste management and disposal is recognized by virtually every study group except for the NRC's Task Force. This major gap in the analysis will only serve to reinforce the public's existing lack of confidence and skepticism, and to lead to increased local political opposition to the establishment of repositories proposed in the future."

[Lash Testimony at 11.]

In this proceeding the NRC staff virtually ignored these nonquantifiable socio-political factors. Clearly Table S-3 does not address such issues. In light of their importance, this is a serious omission.

3. *The History of Past Waste Management Failures Cannot be Conveyed by a Numerical Table.*

There is no question but that the past history of waste management efforts has been checkered with failure and missteps. These past experiences provide important and necessary information for a realistic evaluation of the potential efficacy of the NRC's postulated waste management and disposal system.

Dr. Lash, for example, in his testimony stressed the relevance of historical waste management efforts to future predictions:

"The historical situation at West Valley, and the developing political problems in establishing a geological repository, lead me to disagree vigorously with the Task Force's belief that the ". . . trends in technology and action with regard to nuclear waste indicated a direction that could be used as a basis for some confidence." In contrast to the Task Force's claim to have reviewed several unreferenced documents, ". . . none [of which] is pessimistic with regard to having a successful implementation sys-

> tem." a number of reports have been published recently which are less sanguine. (Citations omitted)
>
> [Lash Testimony at 12.]

Dr. Metlay, who was a member of the special NRC task force reviewing the waste problem, has presented very recently a lucid interpretive analysis of waste management history and concluded, that it is essential to examine past experiences for a realistic appraisal of implementation potential:

> "The persistent faith in a technological fix . . . has resulted in a number of significant distortions. First, the waste management system is implicitly conceived of as being self-implementing . . . A second distortion that has arisen . . . is the very high discounting of factors which may be affected indirectly by the system . . . Nuclear agencies, as well as Congress, ought to reassess their approach to problem solving. That reconsideration will, unfortunately, be painful. Long held traditions and patterns of behavior rarely are altered easily. There are costs—perhaps heavy ones—to be paid. However, it is hard to imagine that any other course of action can yield positive results in the long run. Continued faith in a mythical easy technological fix can push the nuclear agencies only further outside the bounds of reality." [37]

The historical problems in developing and implementing a waste management system have been manifold and widely cited. A commonly cited problem regarding commercial waste in reports is the storage of high-level radioactive waste liquids and sludge in near-surface tanks at West Valley, New York. Removing this waste

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[37] D. Metlay, "History and Interpretation of Radioactive Waste Management in the United States" in Office of Nuclear Material Safety and Safeguards, UNSRC [*sic*], *Essays on Issues Relevant to the Regulation of Radioactive Waste Management*, NUREG-0412 at 13, 15 (May 1978).

from the tanks and disposing of it permanently will be technically difficult and potentially very costly. The genesis of this problem was the initial selection of a final disposal means—perpetual storage in tanks by continually transferring the waste to new tanks—that is now deemed wholly unacceptable.[38] Other problems, such as the fiasco at Lyons, Kansas, and Carlsbad, New Mexico, are generally recognized to have plagued the commercial waste management program so that the goal of having a permanent national waste repository is at least 10 to 15 years into the future.[39]

Despite these failures, and the important contextual information they provide, Table S-3 gives the reader no inkling of this history. Thus Table S-3 fails to provide essential background information for an evaluation of the true impacts of its predicted future waste management and disposal system. The only way to correct this deficency is to provide a narrative describing and assessing the implications of this history.

B. *The Interim Rule Also Is Fundamentally Deficient Because Important Information Is Omitted From Table S-3 And Much Of The Analysis Supporting The Table Is Wrong*

As discussed above, the record demonstrates that *in principle* no numerical table can provide full disclosure of the environmental impacts and risks associated with waste management and disposal, as required by NEPA. A numerical chart, if properly conceived and prepared, however, could be useful in effectively presenting some

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[38] *See generally*, Battelle Pacific Northwest Laboratory, *Alternative Processes for Managing Existing Commercial High-Level Radioactive Wastes*, NUREG-0043 (April 1976).

[39] *See*, U.S. Department of Energy, *Report of Task Force for Review of Nuclear Waste Management* (Draft), DOE/ER-00410 at 12, (Feb. 1978).

of the information on these environmental impacts and risks. Table S-3, unfortunately, is not such a numerical chart, because important items are omitted entirely from the table and some of the values within the table are erroneous.

1. *Adverse Health Effects Have Been Improperly Omitted from Table S-3 and Minimized in the Supporting Analysis*

Most importantly, Table S-3 does not include estimates of adverse health effects in terms of the number of cancers and genetic mutations that will be caused by waste management and disposal operations. Indeed, the possibility of deleterious health effects—the most important environmental impact—is not even presented in an understandable form in the interim rule. Table S-3's discussion of ill-health impacts is limited to an evaluation of "curies released" and "man/rems" [*sic*] of exposure. Any more meaningful, though still inadequate discussion of ill-health issues, is relegated to Appendix C in NUREG-0216. In fact, in preparing the revised table, the NRC staff stated that it did not consider the radiological effects on man from the back end of the fuel cycle to be an environmental impact. When the Hearing Board raised the issue, however, the NRC staff admitted that it was:

> Q. "[By Mr. Briggs] So you don't consider the impact on man to be an environmental impact, then; is that right?
>
> A. [Witness Bishop] Phrased that way I am afraid I hadn't thought about it directly. Clearly insofar as man is part of the envionment, yes, that is an environmental impact. And just as clearly, the impacts on the parameters listed in Table S-3 do have their reflection on mankind in terms of environmental pollution, in terms of radiological impacts and so on.

Q. But you don't include any impacts on man in Table S-3, do you?

A. We did not, that is correct. There are footnotes on the side of the table in the rule which reflect the impacts on man of those environmental parameters listed on the table. But as a part of the rule we took as a given the original format of the rule and did not include direct impacts on man in the table itself."

Tr at 128, 129.

Concerning the evaluation or non-evaluation of adverse health effects, the Chief of EPA's Bioeffects Analysis Branch found the "proposed version of S-3 very disconcerting" and unilluminating:

A. "[Witness Ellett] [I] find at least the draft or proposed versions of S-3 very disconcerting, and *it is impossible to get much idea of what the health effects are from the numbers generated.*

I have talked to people less knowledgeable than myself in the general public that feel that no assessment for risk has been made of nuclear power plants by NRC, and *the reason is the information is totally indecipherable. And if it's indecipherable to me, I think it's indecipherable to the public* . . . 600 man/rem [*sic*] or person/rem [*sic*] means very little to a layman, and unless you know what organs they are talking about, which are never specified in the table, they mean very little to experts.

I think these things have to be laid out so that people can make rational choices, and this is impossible on the basis of S-3 as I see it now. . . . I submit that it [Table S-3] is incomplete." (emphasis added).

Tr at 1046, 1047, 1048.

The importance of including actual ill-health effects in Table S-3 in a form understandable to the public was emphasized even further by the EPA witness during a later exchange in the hearing:

Q. "So let's follow up on that a little bit. You say you don't think it's particularly important that that information be in Table S-3 as long as the information is available in the supplementary sections of the report?

A. [Witness Ellett] I hope our remarks were not interpreted that way. Absolutely not. I think the impact of the activities should be in Table S-3 where people can read it.

Q. You think the dose commitments should be in S-3?

A. As a function of time, yes, sir, on the health effects.

Q. Well, now, if one puts the dose commitment in Table S-3 is there really any reason to put the health effects there, considering the great disagreement among parties as to what they are?

A. I don't think the disagreements are that large, and *I certainly think that it should be in some kind of number that is meaningful to more people than just to experts.* I think I made a previous statement to Dr. Buck to that effect.

I think man/rem [sic] is rather useless as a public information tool.

Q. Well, the question again was isn't it acceptable to take up health effects in the individual licensing proceedings where this can be argued at great length, rather than—

A. I rather doubt it sir. My reason for thinking this is that as you point out it's a difficult, controversial question. I think it would be well to give guidance now and fight it out, these different arguments; perhaps there's less technical knowledge available to the Board than there is at the local area. I think that is putting a burden on the individual EIS things that would waste public monies and goods. These health effects could be put down in some agreed form as approximate estimates, if you will, a range even; but then say, this is the way we look at it. Certainly the individual licensing action isn't the time to argue on what table you use in the BEIR Report, and what's the appropriate plateau for cancer.

I think that thing should be handled generically and I think it's pushing it under the rug to say, well, here's the man/rem [*sic*], *fellows, we'll let it go at that.* (emphasis added).

Tr at 1055-1057

Thus, a principal point made by this EPA witness was that the adverse health effects due to radioactive releases from the backend of the fuel cycle must be included in Table S-3 in a manner intelligible to the public and that in this respect the interim rule is totally deficient. An NRDC witness also stated that the proposed rule is inadequate when judged by the standards of NEPA because, *inter alia*, ". . . radiological impacts are not explained in terms laymen can relate to human health." [Lash Testimony at 3]

In sum, the NRC staff admitted, and additional testimony demonstrated, that radiologically induced ill-health effects on man are important environmental impacts, and that these impacts are not included in Table S-3. This omission renders Table S-3 fundamentally incomplete and inadequate.

The deficiency in the staff's assessment runs deeper, however, than just the omission of ill-health effects in understandable terms from Table S-3. Although the staff did make a calculation in Appendix C of NUREG-0216 of the ill-health caused by the postulated waste management and disposal system, that calculation is incorrect in several important respects. It arbitrarily selects an unduly short time period for its evaluation of the impacts of radioactive releases, it underestimates significantly the ill-health effects caused by exposure to radiation, and it assumes an unrealistically low level of radioactive releases from fuel cycle facilities.

Witnesses for the EPA clearly stated that one of the major defects in the NRC staff's assessment of radiological effects is that its calculations are based on an inappropriately truncated time period. The issue was discussed extensively during the hearing. Below, is some of the exchange that illuminates EPA's view:

Q. "[By Mr. Briggs] Now, what is your position with regard to the length of time over which these health effects should be integrated?

* * * *

A. [Witness Richardson] This is a difficult question, this question of trying to pick a magic number.

I think the answer to your questions, Mr. Briggs, is not going to be given simply, and it can't be given simply.

The objective under NEPA is to assess the total impact to all generations, and to the world's population. I think that's been made clear in a number of different ways.

The difficulty arises from several different sources. One of them is that we have difficulty, since we've been so used to making exact models for specific sites and for short time periods, we have difficulty thinking about long-term projec-

tions, or guesses about what's going to happen . . .

So I would suggest that there is no single number for a cutoff which is appropriate.

What is appropriate is to do the best that we can to calculate the impact as a function of time, as a function of when it's delivered.

So, for example—and I'm not suggesting that these are the correct numbers to use—*one might calculate the environmental dose commitment and then translate that into the associated health impact for a period of 100 years, and then do it, using a perhaps simpler model because it's more difficult to make assumptions, for a period of say 100 to 1000 years.*

And then perhaps it would be appropriate for a few radionuclides to make some kind of at least a qualitative, perhaps quantitative, if you can, assessment of what the impact might be beyond that period of time.

I would like to suggest that that is what this hearing should be producing, those kinds of assessments. For Table S-3, or whatever comes out of this hearing, to arbitrarily truncate the assessment at any particular time period is to make the value judgment that's reserved for later processes.

It's to make the value judgment that those impacts are zero and should not be considered . . ."

(emphasis added). Tr. at 1042-1045.

In sum, the EPA witnesses judged the NRC staff's analysis of ill-health effects, based as it is on an approximately 50 year cut-off point, is seriously defective because it minimizes the ill-health effects associated with the fuel cycle. In order to rectify this deficiency the period of time over which exposures to radiation are calculated would have to be increased substantially. EPA

stressed that such revised calculations are both feasible and necessary. Tr at 1063-1067.

The importance of calculating exposures to radiation over very long periods of time was stressed by other witnesses as well. For instance, Dr. Pohl, a witness appearing on behalf of the Sierra Club, stated that ". . . if you produce time integrals over [only] a period of a few decades, say 40 years, you are really missing very important aspects of some of the isotopic species, and particularly the very long-lived ones." Tr at 1003. Also, Drs. Tamplin and Cochran in their statement addressed this issue as follows:

> "The mathematics of the [NRC's] calculation are such that this dose is equivalent to the dose from 1 year of operation if the radionuclide has achieved its equilibrium concentration in the environment. This would be the case for radionuclides whose mean-life is 40 years (half-life 28 years) or less. For radionuclides with longer mean-lives, the calculated dose would be an underestimate. This is quite important for radionuclides such as C-14, Th-230 and Pu-239 whose half-lives are hundreds of times longer."
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> [Tamplin/Cochran Testimony at 3] [40]

EPA and other witnesses found additional mistakes in the NRC staff's assessment of ill-health effects that resulted in a severe underestimate. One of the EPA witnesses criticized the procedure because the NRC staff calculated radiological effects for only one year's operation of facilities instead of for their lifetimes, and because exposure to the entire worldwide population were not considered:

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[40] Written testimony of Drs. Arthur R. Tamplin and Thomas B. Cochran submitted on behalf of NRDC (October 3, 1977). Hereinafter "Tamplin Cochran Testimony".

[Witness Richardson] "[N]ow, it's not easy to follow what was done in these calculations, but to the best of our ability to gather how these things were calculated . . . a calculation was done of the dose commitment to individuals in the U.S. population from one year of release. And those dose commitments were carried out for as long as the material resided in the body of the individual after that year's intake . . .

It is the sum of doses to populations resulting from the activity involved, and that means the sum of doses to all individuals, world-wide, for the life of that facility for releases over the life of the facility; the impact statement is considering whether the facility should be there or not, not whether it should be there one year or not but over the life of the facility for as long as the material persists in the biosphere . . ." (emphasis added)

Tr at 1052-1053.

For instance, one of the EPA witnesses strongly criticized the staff's reliance on GESMO documents in Appendix C of NUREG-0216:

A. [Witness Ellett] I seem to be the only one that has a strong opinion on that, and I very definitely feel that's true.

I feel that GESMO documents are technically incorrect in a number of areas and do not provide the information to trace the numbers that they give for their dose or health effect estimates.

Myself and my staff have spent a fair amount of time with the GESMO documents, and we think they're almost useless for this purpose.

Tr. at 1021-1022.

EPA witnesses also disagreed in part with the assessment of ill-health effects contained in the so-called Ras-

mussen report, which assessment apparently was used to some extent in the staff's analysis in Appendix C. Tr. at 1040-1041.

Similarly, the written testimony of Drs. Tamplin and Cochran describes numerous shortcomings in the staff's analysis that cause the staff to underestimate seriously the ill-health effects caused by radioactive releases from the fuel cycle. Combined with the failure to use the environmental dose commitment concept, they found that overall "[t]he estimated dose commitments in GESMO and NUREG-0216 . . . are too low by orders of magnitude." Tamplin/Cochran Testimony at 12. Dr. John Gofman similarly concluded in his written testimony that due to, among other things, use of the absolute risk model and out-dated data, the NRC staff's analysis was sorely deficient. Dr. Gofman stated:

> "[T]he treatment of health effects in Appendices C and I of NUREG-0216 is totally unsatisfactory and does not meet the high standards required for full disclosure of the impacts on public health of the nuclear fuel cycle. The Task Force has chosen exclusively those references that minimize the health effects per rem, neglecting a substantial body of literature that would have led it to a considerably higher estimate of health effects per rem. The Task Force also has been unrealistically optimistic concerning likely releases of radioactivity from the fuel cycle and the consequent population doses."
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> [Gofman Testimony at 1] [41]

In sum, several witnesses found that virtually in every respect the NRC staff's analysis of ill-health effects was flawed and that the staff dramatically underestimated those effects.

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[41] Written testimony of Dr. John Gofman submitted on behalf of the Sierra Club (October 3, 1977).

2. *Cumulative Impacts have been Improperly Omitted from Table S-3*

Another major omission from Table S-3 is the lack of an assessment of the cumulative environmental impacts. The cumulative assessment should include 1) an analysis of the impacts of waste generated to support an individual reactor for its entire 30 to 40 year operating life span, and 2) an analysis of the impacts of the wastes generated by all reactors throughout the country operating for their expected life spans.

The NRC staff acknowledges that although it is appropriate to inquire into these cumulative effects, the values in Table S-3 are not adequate to disclose them:

> "The basis for the analysis used in this survey is the impact of a single model reactor operating for a single year. Reactors in fact operate for 30-year periods, and more than one reactor is operating at any given time. There is thus reason to inquire about the cumulative impacts attributable to the reprocessing and waste management aspects
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> * * * *

**[PORTION OF FINAL WRITTEN STATEMENT ON BEHALF OF COMMONWEALTH EDISON, *ET AL.*
(June 26, 1978)
(CHAPTER VI)*]**

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Hearing Board

Docket No. RM-50-3

IN THE MATTER OF
URANIUM FUEL CYCLE IMPACTS FROM SPENT FUEL
REPROCESSING AND RADIOACTIVE WASTE

FINAL WRITTEN STATEMENT ON BEHALF OF COMMONWEALTH EDISON COMPANY THE DETROIT EDISON COMPANY EXXON NUCLEAR COMPANY, INC. NIAGARA MOHAWK POWER CORPORATION OMAHA PUBLIC POWER DISTRICT POWER AUTHORITY OF THE STATE OF NEW YORK PUBLIC SERVICE COMPANY OF INDIANA, INC. ROCHESTER GAS AND ELECTRIC CORPORATION

JAMES P. MCGRANERY, JR.
M. REAMY ANCARROW
WALTER T. ECCARD

LEBOEUF, LAMB, LEIBY & MACRAE
1757 N Street, N.W.
Washington, D.C. 20036

June 26, 1978

Technical Consultants
William W. Lowe
Thomas E. Potter
Pickard, Lowe and Garrick, Inc.
1200 18th Street, N.W.
Washington, D.C. 20036

[* For Chapter VI, see Certified Index of the Administrative Record in Docket Nos. 79-2110 and 79-2131 at Vol. 30, Doc. No. 10.]

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Chapter VI

FEDERAL REPOSITORY

The Staff model in NUREG-0116 and NUREG-0216 estimates the environmental effects of the disposal of HLW and/or Spent Fuel in a deep geologic Federal Repository ("Repository").[1] This model postulates emplacement of this waste in a salt bed that is laterally extensive and thick (approximately 200 feet) at a depth of 1000 to 4000 feet in an area of low tectonic activity and with minimal impact with valuable natural resources. NUREG-0116 at 4-73; *see also*, CommEd, TVA, BG&E/IWS at VI-4. Such a Repository could accommodate the HLW and TRU waste from 4000 RRY in 2000 acres of underground development. NUREG-0116 at 4-79

The Staff model contemplates that the waste will arrive at the site and will be temporarily stored at the site (for approximately one week) while it cools. There is no technical reason why this interim storage period could not be expanded. Since the environmental impacts from surface storage are minimal in any event, extension of the interim storage period is not a matter of major concern. In addition, above-ground storage at the Repository for long periods is unlikely since, if operations were interrupted, the shipment of waste to the Repository could be rescheduled. CommEd, TVA, BG&E/FRA to CERCDC/FRQ III. The waste will then be transferred down a shaft by conventional techniques and emplaced in a long-term disposal configuration. NUREG-0279; CommEd, TVA, BG&E/IWS at VI-5. The waste will be handled and transported at the Repository by shielded

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[1] The impacts of the S-3 Table are calculated on the basis of a reference reactor year that is, for a 1000 MWe light water power reactor operating at an annual 80% capacity factor. These impacts are independent of projections of the number of actual operating reactors and their capacity factors. NRC/FRA to OH, WI, & NY/FRQ 1.

vehicles to minimize occupational dose. NUREG-0116, at 4-113; NRC/FRA to OH, WI, & NY/FRQ 19.

Pursuant to Commission Memorandum (January 26, 1978), this proceeding considered only two waste disposal options: no-recycle and uranium-only recycle.[2] NUREG-0116, Ch. 3. In the no-recycle option, the Spent Fuel assemblies will be placed in the Repository. In the uranium-only recycle option, HLW from the reprocessing plants will be placed in the Repository after solidification. While both waste forms will be brought to the Repository at approximately the same time (ten and a half years after use), the Spent Fuel has a ten percent higher initial heat generation rate. Tr. 551. The total heat released from the Spent Fuel over a period of 1000 years would be about three times the heat from a corresponding quantity of HLW. CommEd, TVA, BG&E/FRA to NRDC/FRQ 12. As noted by the Staff, over a period of 100,000 years, the time-integrated heat-load of Spent Fuel is about 10 times greater than that of HLW per ton of Spent Fuel reprocessed. NRC/FRA to NRDC/FRQ at NRC 7-73. If Pu is treated as a waste and stored with the HLW, then the heat generation rates produced by the two cycles are roughly equivalent. Tr. 552-53. The Staff has indicated that retention of Pu in the HLW will result in a maximum increase in the solid waste repository area of about 25% from the added heat. The environmental impacts of these changes are discussed in § 4.5.2 of NUREG-0116. NRC/FRA to CERCDC/FRQ VI. 3. Thermal loading criteria can be modified to preclude effects from long-term heat load. CommEd, TVA, BG&E/FRA to WI/FRQ 42. During the first round of questions and answers the Staff summarized other significant differences between HLW and Spent Fuel. NRC/FRA to CERCDC/FRQ V.D. 1.

The implication of the difference in heat generation rates is reflected in the area required to store the wastes

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[2] *See also* NRC/FRA to CERCDC/FRQ VI. 1.

from both cycles. Comparing Spent Fuel to HLW, the Staff recognizes that Spent Fuel requires several times as much storage space as HLW. It is useful to note at this point that the spacing required to limit the temperature of Spent Fuel in the Repository is greater than the spacing required to prevent criticality. Thus the likelihood of a criticality accident involving Spent Fuel at the Repository is slight. NRC/FRA to CERCDC/FRQ V.D.2.

This analysis addresses the concerns expressed by Dr. Resnikoff. SC/IWS (Resnikoff) at 22, App. D at 15. These concerns questioned the Staff conclusions that the required space for both fuel cycle options is approximately the same. One answer to this concern is that since the heat generation rates from waste from the two cycles are essentially the same (when Pu is treated and disposed of as a waste), the required land volume for this disposal is also equivalent. Additionally, the Staff has noted that the design of a waste Repository must provide for the thermal output of the waste. The Staff, as evidenced in its response to an NRDC question, will ensure that in any facility it licenses, consideration is given to waste emplacement heat loading for both the operational and long-term storage phase. NRC/FRA to NRDC/FRQ at NRC 7-73.[3] The second answer to SC's concern is

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[3] *See* NRC/FRA to OH, WI, & NY/FRQ 15. The Deutch Report, prepared by DOE (which has responsibility for developing a Federal Repository), demonstrates DOE's awareness of the need to design a Repository to meet these different heat needs. Specifically, the Deutch Report notes that "solidified HLW could be placed with an initial heat loading of 150 KW/acre if the waste has decayed 10 years since its initial generation in a reactor. Spent Fuel elements of the same age could be emplaced at a density of 60 KW/acre." DEUTCH, *Report of Task Force for Review of Nuclear Waste Management (Draft)*, Department of Energy, 56 (February, 1978) [hereinafter Deutch Report]. While the Staff has recently revised its heat loading calculations from 150 KW/acre to 106 KW/acre, the impact from that change is on land use which has consistently been insignificant. In addition while the actual volume requirements may change, the major point is that DOE, the agency charged with

that both NRC and DOE are aware of the characteristics of Spent Fuel and HLLW [*sic*] and the resulting storage requirements of each.

The record in this proceeding supports the conclusion that deep geologic storage of the waste described above is technologically feasible. This conclusion is also supported by the Deutch Report.[4] In that report the Task Force concluded

> A majority of independent technical experts have concluded that high-level waste (HLW) can be safely disposed in geological media, but validation of the specific technical choices will be an important element of the licensing process. Deutch Report at 2; *see generally* Bredehoeft at 2.

During the examination of the Staff, the Hearing Board explored the compatibility of the criteria being developed by NRC with the criteria being developed by DOE with emphasis on the technological feasibility of a Repository.

Since NRC will have the responsibility of licensing any Repository constructed by DOE, it must maintain a certain distance from DOE's initial work to protect the integrity of that licensing process.[5] While the Staff is necessarily circumspect in the manner in which it interacts with DOE, it is aware of DOE's progress in developing a conceptual design for a Repository. NRC/

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developing a Repository, is aware of the different heat loading requirements for HLW and Spent Fuel. *See also* Bredehoeft *et al.*, *Geologic Disposal of High-Level Radioactive Wastes—Earth-Science Perspective*, U.S.G.S. Cir. 779, at 5 (1978) [hereinafter Bredehoeft].

[4] The only issue is the choice of particular sites and modes of operation for the best result; that issue, however, is outside the scope of this proceeding. This proceeding, rather than choosing the best approach, is to estimate impacts on a conservative basis unrelated to a particular site.

[5] *See* NRC/FRA to NRDC/FRQ at NRC 7-212.

FRA to CERCDC/FRQ V.C.2. In spite of this necessary independence, the record supports the conclusion that parallel development is taking place in a sound manner and that the two agencies have not been operating in two different worlds. The general criteria that must be met in planning and constructing a Repository are known and generally agreed upon. Tr. 537, 542 and 920. Representatives of DOE and NRC have met to discuss the criteria. Tr. 535. In addition, a proposed rulemaking is expected this summer to formally establish certain of the initial criteria. This, of course, will provide additional information for DOE to use in preparation for a licensing proceeding. *See* NRC/FRA to CERCDC/FRQ V.C.4. It, therefore, is reasonable to conclude that these separately developed criteria will be compatible.[6]

While the Staff again was cautious about prejudging the licensability of the model site[7] (in the event that an application for a site with those same characteristics is submitted in the future), it did conclude that there was nothing in the model site which would make it unacceptable from a licensing standpoint, that there is no good reason to believe that the calculated impacts are too high to be licensed, and that "there are probably hundreds, if not thousands of sites which would provide isolation of these wastes from mankind to some reasonable degree." Tr. 648-50.[8] Further detailed analyses of specific prob-

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[6] Additional data which will aid the two agencies in a coordination effort will flow from the scheduled demonstration DOE WIPP that will be used as a "geologic ultimate disposal location" for TRU defense waste, "and as a facility in which to perform R&D with other waste materials in salt." Demonstration disposal of spent fuel will also be considered. Deutch Report at 3.

[7] *See* NRC/FRA to OH, WI, & NY/FRQ 17.

[8] *See* NRC/FRA to OH, WI, & NY/FRQ 18. In that answer the NRC Staff indicated thirty-six *states* (each of which could have several potential sites) are being considered for location of the Federal Repository. This underscores that there are a number of potential Repository sites. Further, as the Staff indicated in re-

lems will not be possible until after a site is selected and site specific data is gathered. NRC/FRA to CERCDC/FRQ V.F.I.

Finally, as to the technological feasibility of a Repository, recent studies by knowledgeable, authoritative and independent groups have concluded that existing technology can be applied to construct an [*sic*] operate a geologic Repository for HLW in a safe and environmentally acceptable manner. Deutch Report at 2; S. Keeny, *et al.*, *Nuclear Power, Issues and Choices* (Ballinger, 1977; "Study Finds Nuclear Waste Technology Sound", *Chem. and Eng. News*, p. 17, May 9, 1977.[9] As the Staff testified, there is a "consensus throughout the world that the most prudent course of action is to seek a suitable site or set of sites for geologic disposal of high level nuclear waste." Tr. 650; Deutch Report at 2.

The assumptions that have gone into creating the Staff model for the Respository, as with the assumptions in other areas, are conservative and therefore the projected environmental impacts are similarly conservative. Three examples from this proceeding illustrate the conservative nature of these assumptions with respect to the Repository.

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sponse to another question from Ohio, Wisconsin and New York, it has not identified any single criterion that would clearly exempt a site from consideration. NRC/FRA to OH, WI, & NY/FRQ 25. *See also* NRC/FRA to OH, WI, & NY/FRQ 23(b).

[9] A number of foreign countries are operating repositories in deep geologic formations for the disposal of low and intermediate-level waste. NRC/FRA to OH, WI, & NY/FRQ 9. For a discussion of foreign waste disposal activities see Deutch Report at 94-102. The initial written statement of Dr. Lash, submitted on behalf of NRDC, raising uncertainties about the feasibility of constructing a geologic Repository is answered; the conclusions of the Deutch Report support the conclusion of feasibility. NRDC/IWS (Lash) at 13; Deutch Report at 2. Also a number of foreign countries have similarly concluded that geologic containment of this waste can be achieved. Deutch Report at 6-7.

First, the Staff's model postulates complete release of all gases from Spent Fuel stored at the Repository.[10] Spent Fuel elements are surrounded by cladding, however, and will be placed in a protective canister. Packaging of unfailed fuel elements decreases the probability of mechanical damage and prolongs the life of the cladding by controlling the environment near the cladding. Various approaches are being considered to offset the resulting increased heat that results from this packaging. NRC/FRA to CERCDC/FRQ VII.7. In spite of this dual protection, the Staff model took no credit for the extra containment tnat will result from this added protection. Tr. 563. The relevant testimony reads

> . . . there would be some extra protection from the . . . cladding itself. Secondly there would, of course, be some protection by the fact that much of the gas in occluded [*sic*] within the fuel pellet itself. On the other hand, in our analysis all we assumed in the way of that protection is that it would remain intact long enough to backfill the mine. At that time, we allowed *all* the gas to be released. And, in fact, it was released to the atmosphere . . . we are virtually certain that not all the gas would escape to the atmosphere. Tr. 563-64. (Emphasis added).

This extended quotation indicates that the Staff recognizes that the projected environmental impacts are conservative (*i.e.*, postulate releases that are not likely to occur) and additional protective devices which will be used are given little, if any, credit.

The second example of Staff conservatism concerns the effectiveness of multiple barriers that will be used in

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[10] As noted by one participant in this rulemaking and confirmed, by the Staff, licensing effluent limitations will result in lower environmental impacts. The Staff concludes that release of all gases at the Repository is an event of "low probability." Thus, the Staff analysis is conservative, indeed overly conservative. NRC/FRA to EPA/FRQ 1.

a Repository. These barriers include administrative, engineering, and geologic barriers. The Staff model relies only on the geologic barrier even though it admits that the other barriers would provide protection for significant periods of time. Tr. 618.[11] By not taking any credit for the protections afforded by these other barriers, the impacts from a Repository are again overestimated.

The third example of inherent conservatism in this model is described in our Initial Written Statement. The Staff has postulated a release rate of 0.3%/yr.$^{-1}$ (i.e., leach time of 333 years) whereas a leach time of 10^5 yr. is more appropriate. CommEd, TVA, BG&E/FRA to NRC/FRQ 14. Dr. Hoyt Whipple for PLF introduced evidence based on a study of 2000 years old Phoenician glass that indicated that a leach rate of 0.3% per year is too high for waste bonded in a glass-like mass. PLF/FRA to NRC/FRQ 1a. The 10^5 year leach time is more appropriate since that is the leach time typical of borosilicate glass, the form in which HLW will be stored. This leach time is primarily a characteristic of the solidified high-level waste form properties. CommEd, TVA, BG&E/FRA to NRC/FRQ 14. During the first round questions and answers, the Staff, in response to an NRDC question, noted that in a "semi-large" test conducted with blocks of HLW in ground water in Canada, leach rates after 15 years of burial are decreasing and are about 10^5 times lower than leach rates determined in the laboratory. This tends to support our conclusion that the Staff's leach rate selection is overly conservative. NRC/FRA to NRDC/FRQ at NRC 7-93. Testimony in this proceeding suggests that the leach rate of Spent Fuel material appears to be comparable to that of HLW. Bredehoeft at 7; *but see* NRC/FRA to CERCDC/FRQ V.F.4. Using the more appropriate and still conservative 10^5 yr leach time the maximum individual dose is *three* orders of magnitude lower

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[11] As the Staff has indicated, salt is quite impermeable to heavy gases. NRC/FRA to NRDC/FRQ at NRC 7-125.

than that which results from using the Staff model. This demonstrates the differences which result from using assumptions that are more conservative than is necessary to estimate fairly environmental effects based on currently available technology and data.

These three examples reflect the Staff's approach in postulating a model facility and conservative environmental effects that follow from the use of that facility. Throughout its analysis the Staff predicts releases and environmental impacts that do not provide for use of currently planned and admittedly effective protective devices to limit environmental impacts from the Repository. While such an approach can be described as conservative (projecting maximum impacts), a more accurate approach would produce environmental impacts significantly lower than those contained in the proposed rule. It is therefore appropriate to conclude that the possibility of exceeding the estimates in NUREG-0116 is quite small. CommEd, TVA, BG&E/FRA to NRC/FRQ 13.

Currently an operational Repository does not exist in this country, but there has been experience at Lyons, Kansas and in New Mexico on developmental work for a Repository. At Lyons there was a commercial salt solution mining company nearby, and a question was raised concerning the possible connection, via underground cavities, of the two sites. This led to a concern on the part of some individuals and organizations that there might be water migration to the disposal site. It was not established that such migration had occurred, but the concern over this possibility led to political pressures which resulted in Congressional action restricting the use of Lyons as a permanent waste storage site. Tr. 569. Further, at Lyons questions were raised as to whether some abandoned mine shafts or oil wells violated the integrity of the salt vault. For example, when oil wells were drilled in Kansas (at the turn of the century) records were not kept on where the wells were drilled, and when these

wells were abandoned they were not plugged. Now, with changes in the law and technology, accurate records are kept as to the location of all such wells and the holes are plugged. Tr. 720-21. Thus the likelihood of encountering problems similar to those found at Lyons is small.

Two positive points should be made concerning the experience at Lyons. First, the Staff model *avoids* the major problem described above since one of the licensing criteria for the model facility is that a Repository *not* be in an area where there has been previous drilling. NUREG-0116 at D-3. This is another example of the model incorporating lessons learned from past experiences to control and minimize environmental impacts. Therefore, attempts to attribute potential integrity problems at the Lyons site to the model site are misdirected.

Second, while Lyons was ruled out as a permanent disposal site, it was used for a series of experiments and thus produced a great deal of valuable data on the properties involved in disposal in a salt medium. *See* Tr. 907-14; NRC/FRA to CERCDC/FRQ V.D.4. Nothing in this data suggests that salt is not a satisfactory medium for long term disposal of HLW. Project Salt Vault and associated programs examined the basic physical, chemical, and radiological phenomena pertinent to the use of salt as a HLW disposal medium and found it satisfactory.[12] CommEd, TVA, BG&E/FRA to CERCDC/FRQ II-5. Indeed, many factors suggest that salt is a preferable medium over other rock media. For instance, the thermal conductivity of salt is approximately three times higher than that of average rock thereby facilitating heat dissipation. See PLF/IWS Att. A at 4. Also, with respect to heat dissipation, the Staff's answers in the first round of questions also indicated that the Staff has identified

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[12] A number of foreign countries have also concluded that salt is a satisfactory medium for the placement of a repository for nuclear waste disposal. *See* NRC/FRA to OH, WI, & NY/FRQ 10; *see also*, Deutch Report at 6-7.

site specific problems at the Lyons site on surface temperature rise. This knowledge will enable the NRC to refine its criteria and therefore determine if a specific Repository should be licensed. NRC/FRA to CERCDC/FRQ V.E.2.

Good experience was also gained in preliminary work in New Mexico. There one of the actual drill holes encountered unpredicted pressurized gases and brine just below the salt formation. This anomaly was attributed to the nearness of a geologic feature, the Capitan Reef.[13] The study area was therefore moved a small distance (a few miles) to avoid the reef and to find an area which had greater geologic uniformity. Tr. 637. The significant point is that it was possible to find an acceptable study area within the immediate vicinity of the first site. Additionally, the record reveals that there are a number of techniques, many of them seismic, that allow man to determine the boundaries of salt beds and the hydrogeologic regime at the edge of the bed. A summary of the various techniques for remotely exploring the characteristics of rock appears in Bredehoeft at 4. Use of those alternatives will reduce the number of boreholes and therefore minimize the disturbance of the rock's integrity. Furthermore, a description of this information will be required in the criteria for a Repository. Tr. 638. Thus, once again, current practice improves based on past experience, and the technology currently exists to implement such improvement.

Problems or accidents potentially associated with a Repository can be divided into two segments: (1) those that might occur prior to permanent emplacement of waste in the Repository and (2) those events that might occur after emplacement of the waste in the Repository. It should be noted that the Staff's model postulated that the waste for Repository will be stored above ground at

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[13] *See generally* Bredehoeft at 5.

the Repository site for a short period of time prior to emplacement. Thus there are three possible accident situations at the Repository: an accident could occur during temporary storage, during movement of the waste from the temporary storage site to underground storage, or after underground emplacement.[14]

While the waste is temporarily stored at the surface (in either a cooling pool or air cooled chamber), the possible events that could cause accidental releases include an aircraft or meteor impacting on the disposal site. The probability of these accidents actually occurring is extraordinarily small. The Staff postulated that the likelihood of a meteor impact is 2×10^{-14}/yr. Tr. 628. In our Initial Written Statement we indicated that the likelihood of all impact accidents is 7×10^{-12}/yr. Our projection (slightly higher than the Staff projection because it includes all potential impacts) means that one significant impact is expected every *one hundred and forty billion years*, a negligible risk. CommEd, TVA, BG&E/FRA to NRDC/FRQ 7. If there were such an impact while Spent Fuel was stored temporarily above ground, there could be a release of gaseous radioactivity (*e.g.*, Kr-85). If ten tons of Spent Fuel were above ground at the time of impact (that would be either 20 PWR or 50 BWR fuel assemblies), the total radiation dose at one mile resulting from this gaseous release would be 4×10^{-2} *mrem*. CommEd, TVA, BG&E/FRA to NRDC/FRQ 8. Given the probability of such an event *ever* occurring, this potential exposure can accurately be described, at worst, as a trivial risk. Further, in the event of such an accident, considerations of occupational dose exposures are relatively unimportant since the severity of the accident itself would be the major source of health hazards.

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[14] For a detailed discussion of the planned activities involved in transferring waste at the Federal Repository, see NRC/FRA to OH, WI, & NY/FRQ 19.

When the waste is transferred from its storage above ground to its permanent disposal below ground, the possibility of an accidental crane drop exists. The CommEd, TVA, BG&E/IWS stated that the probability of such an accident is $5 \times 10^{-4} yr^{-1}$. To put this probability figure into perspective, it is helpful to note that such a probability implies that one drop accident will occur every two thousand years. In any crane drop accident, very few canisters will be involved since only one canister is handled at a time. This, of course, further minimizes the likely impact from any single accident. CommEd, TVA, BG&E/IWS at VI-6; CommEd, TVA, BG&E/FRA to NRDC/FRQ 7. In addition, little or no occupational exposure from any crane drop accident is expected since these operations will be remotely conducted in a hot cell. CommEd, TVA, BG&E/FRA to WI/FRW 33.

In this proceeding more attention was directed to accidents or releases that would occur after the waste is emplaced underground. The primary concern is that the integrity of the underground storage facility will be breached, and that humans will come in contact with these wastes. This facility failure could occur because of either natural or man-controlled events. Examples of natural events causing site failure include another ice age or a severe earthquake. Man-controlled events could include shaft seal failure, exploration and drilling into the disposal site, cracking in the geologic barriers caused by heat expansion and/or contraction, and dissolution of the surrounding geologic medium. In both classes of situations, the events could permit water to come in contact with the buried waste, facilitating migration of the waste. It is important to keep in mind that for human exposure to the waste to occur there must be a method of ingress to expose the waste to various migration routes and a place of egress to bring the waste in contact with humans.

The record in this proceeding indicated that the likelihood of a natural event leading to exposure of the waste

is vanishingly small. For instance, the Staff analysis has considered the problem of another ice age. Tr. 614. Any site selected by DOE and approved by the NRC will include investigations into past geologic evidence so that it will be possible to conclude that any erosion caused by another ice age would *not* erode through the cap rock covering the salt where the waste will be buried. Tr. 615. This conclusion was not challenged by EPA's testimony in this proceeding. Tr. 735. In that testimony, USGS indicated that land surface erosion caused by an ice age could be as much as several hundred feet. *Id.* Since, however, the model Repository will be at a depth of 1000 to 4000 feet, even this amount of erosion would not disturb the integrity of the Repository. Thus, it is proper to conclude that the likelihood of a natural event leading to human exposure to buried waste in the Repository is extremely low.

If water is introduced into the Repository, then it is necessary to consider two separate steps to calculate the likelihood of the waste coming into contact with humans. These two steps are the leach rate and the waste migration rate. The leach rate is the rate at which the contaminated materials are removed from their container. The migration rate is the rate at which the material moves through the ground after it is leached from its container.

As discussed above (see page 11, *supra*) the Staff has postulated a leach rate of 0.3% per year. That discussion suggested that a more realistic figure is a leach time of 10^5 years. In addition, other testimony in this proceeding strongly suggests that the migration rate similarly may be overconservative. *See, e.g.*, PLF/IWS (Goldsmith) at 8. Studies at Oklo in Gabon, on the west coast of Central Africa (where a natural nuclear reaction occurred), suggest a much lower migration rate than currently postulated. *Id.* Preliminary analyses of the Oklo data indicate that the movement of fission products away

from the reactor site, if any such movement has occurred at all, takes place at a very slow rate. Thus it appears that after approximately 1.8 billion years there has been no detectable movement of Pu. *Id.* As amplified by Dr. Whipple during the oral portion of this rulemaking, the Oklo migration rate data are relevant to discussion of the model Repository since at Oklo there were no planned barriers to slow down the migration rate. Tr. 769-75; *see also* CommEd, TVA, BG&E/FRA to WI/FRQ 25. In attempting to discount the relevance of the Oklo data, Dr. Lash for NRDC failed to comment on the significance of the addition of planned barriers in the model Repository. NRDC/FRA to CommEd/FRQ 13. At the Repository there will be design features added to the natural conditions to limit further migration. Therefore, if the actual migration rate at a natural, unplanned site is lower than the Staff's projections, the migration rate at a designated facility should be even lower. Thus it is probable that the migration rate is lower than that projected by the Staff.

The importance of the leach rate and migration rate, however, must be considered in context. The magnitude of the exposure is also a function of path length, the area of human exposure, and adsorption properties of the surrounding media. Tr. 605. Obviously, the longer the path length and the greater the adsorption properties, the less significant any eventual release will be. It has been recognized by other parties in this proceeding that the existence of multiple barriers also further inhibits the movement of waste. For instance, the following testimony of the USGS is instructive: Q: "So that in a sense you do have some multiple barrier situations here? A: Yes. . . . The waste form itself . . . is a barrier. The mechanical body of rock is a barrier. And the groundwater is also." Tr. 716-26.

One way in which water could be introduced into the Repository is by man, at some future time, drilling a

hole in the Repository. This possibility underscores the importance of the Staff's model criteria. As noted above, one criterion for a Repository is that it not be placed in an area where there are valuable natural resources. The rationale behind this criterion is that it reduces the likelihood of exposure of the waste buried at the Repository as a result of drilling activity exploring for those resources. (This criterion reinforces the choice of salt beds for a Repository since salt is quite plentiful in the United States.)

During the proceeding, some questions were raised concerning the possibility that the heat produced by the waste in the Repository could lead to expansion and then contraction of the salt dome or the rock covered over the salt which could cause cracking and thus, a route for water to enter the Repository.[15] Some studies have shown that the confining layer above the salt would not be perturbed by this heat. Tr. 707. Representatives of the USGS indicated that this issue of the mechanical properties of salt is a subject outside of their areas of expertise. Tr. 708. Nevertheless, in evaluating the potential significance of this problem, there is helpful information with past experiences from the Lyons, Kansas site discussed above. This experience, plus data from other mine sites, indicates that by knowing "the thermal properties of the formation and the stratigraphy above it, that those factors [i.e., potential cracking] can be taken into account in designing a facility." Tr. 907-08. Thus individual sites may have to vary the total load of waste placed in the Repository and/or the distribution of the thermal load in the Repository. These adjustments are technical matters and the available evidence indicates

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[15] *See* Bredehoeft at 6; NRC/FRA to CERCDC/FRQ V.A.2(a & c). It must be remembered, however, that for Repository failure (*i.e.*, waste exposure to humans) to occur, there must also be a pathway through which the waste may migrate out of the Repository.

they can be accurately predicted and suitably implemented. Tr. 908. This same conclusion was reached by Dr. Cohen, a witness for the Pacific Legal Foundation. Tr. 807. The Staff has also testified that thermal considerations will be reflected in Repository design criteria. Tr. 586. Thus this problem has been recognized, is solvable, and will be factored into any design of a site.

Another potential pathway for water migration into the Repository is through failure of the shaft seals. Tr. 612. The simple answer to this is that a reduction in the number of test holes drilled to determine site suitability will reduce the probability of the potential failure mechanisms. Further, as described above, alternatives to drilling for gathering site specific information are available and are being reviewed. Bredehoeft at 4. The model facility is designed so that the shaft will be filled with sand or sand-like material and will be sealed to protect against water migration. A variety of suitable materials, including possibly cement or crushed salt which would re-crystallize under lithostatic pressure, also could be used for shaft backfilling. CommEd, TVA, BG&E/FRA to CERCDC/FRQ III-2. The Staff has supplied information on the field experience in plugging boreholes of up to about 12 cm. diameter, and current plugging techniques are adequate for such small diameter holes. NRC/FRA to CERCDC/FRQ V.G.3. Results from an experimental demonstration project with seals for larger boreholes will be available within two years. Initial results from this project suggest that the shaft sealing can be done with an integrity greater than the original rock. Tr. 808. Further, even with seal failure, the material would have a long pathway to an aquifer, which coupled with the ion exchange capacity of the coarse material filling the shaft, reduces the potential exposure to humans. Tr. 912.

A final possibility of Repository failure is for water to pass through the geologic salt formation, dissolving the salt that isolates the waste and thereby facilitating mi-

gration of the buried waste. The possibility of circulating groundwater contacting emplaced waste depends primarily on: (1) the probability of fractures which penetrate to the Repository occurring, (2) the fractures being large enough to provide significant pathways and (3) a sufficient source of water to provide significant salt and waste dissolution and waste transport mechanisms. The geologic history of salt formations which might be used to house a Repository indicate that these circumstances have not materialized for periods of up to 250 million years. CommEd, TVA, BG&E/FRA to NRC/FRQ 3. Salt has been chosen as a favored disposal medium because of its resistance to water dissolution. Uncontroverted testimony from three different participants in this proceeding documented this property of underground salt formations. The Staff testified that

> . . . in southeast New Mexico, it is quite well known that the salt fronts at the edges of that major salt bed in the Permian Basin are being dissolved away at a rate . . . of a mile or so per million years. Tr. 611.

Testimony by the USGS substantiated this dissolution rate of one mile per million years. Tr. 718. Testimony by the Pacific Legal Foundation illustrates the significance of this dissolution rate. Dr. Cohen testified

> . . . the thing that gives me perspective on this, though, is this calculation I did on this New Mexico site, that if all the ground water now flowing through all the aquifers above the salt formation were diverted to flow through the salt formation, it would take 50,000 years to dissolve away the salt enclosing one year's waste. Tr. 819.

For this form of dissolution to take place a major event (either natural or man-made) would have to occur. The very low probability of such an event happening has been described above. If such an event did occur, the dissolu-

tion rates indicate that the salt itself will provide a significant measure of protection against unplanned human exposure.

After the water reaches the waste, a further delay preventing the wastes from reaching the environment exists. This delay results from the time that is needed for the waste-containing glass to be leached before the waste can enter the ground water. Even after the glass has been leached, further delays result from water transport obstacles. It has been estimated that it would take waste-containing water "many hundreds, or even thousands, of years to reach the surface." PLF/IWS Att. A at 11.

One participant in this proceeding, CERCDC, has criticized the Staff model for not calculating the environmental impacts from alternative (*i.e.*, non-salt) repository models. *See, e.g.*, NRC/FRA to CERCDC/FRQ V.B.1; CERCDC/FRA to PLF/FRQ 6. Such criticism reveals a lack of understanding of the purpose of both Table S-3 and this proceeding. NUREG-0116 and NUREG-0216 are unmistakably clear in describing the scope of this rulemaking. On page 3-5 of NUREG-0216 the following instructive statement appears:

> . . . the Task Force gave in-depth treatment to only one set of alternatives for waste management and reprocessing. This was considered adequate for illustrating and illuminating the issues involved, which was the Task Force's charter. The report was not intended to be a generic consideration of all alternatives or a selection among them, in terms of policy.

The Supreme Court has upheld this approach. *Vermont Yankee v. NRDC*, 46 U.S.L.W. 4301 (1978), *rev'g* 547 F.2d 633 (D.C. Cir. 1976). The rationale for such an approach is straight-forward. If a rock formation other than salt were chosen for the Repository it would be required to meet the overall impacts described for salt. Placing a Repository in another rock formation would

likely result in numerous design detail modifications (*e.g.*, spacing around fuel elements, pillar arrangement). These changes, however, would not alter the fundamental conclusions in Table S-3 on estimated environmental impact. Numerous other rock formations could house a Repository.[16] Repositories in these alternative rock formations, however, will produce environmental impacts of the same degree as those postulated for the model site especially given the conservatism of the estimates being made. Tr. 589; NRC/FRA to OH, WI, NY/FRQ 26. Thus, detailed descriptions and evaluations of alternative sites for a Repository are neither required nor desirable.

Other disposal options are also theoretically possible. One such option is seabed disposal. The advantages and disadvantages of this disposal method were reviewed in detail by the Staff in this proceeding. NRC/FRA to OH, WI, NY/FRQ 30. The difference in expected environmental effects accompanying final disposal in each type of geologic formation should be so small as to be essentially meaningless. CommEd, TVA, BG&E/FRA to WI/FRQ 24. In any event, since the largest part of the environmental impact of waste disposal results from activities other than final geologic storage, variances in the media for storage have insignificant effects on the total impact assessment. CommEd, TVA, BG&E/FRA to WI/FRQ 26. To the extent that alternative Repositories could operate with smaller environmental impacts than the model facility, the adequacy of the model facility for this proceeding is reinforced since it becomes more conservative.

The development of an operational Repository is currently a matter of high priority. At the time this proceeding began, DOE (the agency charged with con-

[16] It should be noted that DOE has responsibility for selecting sites for a Repository. DOE's evaluation of potential media for geologic disposal is discussed in NRC/FRA to OH, WI, & NY/FRQ 28. See Deutch Report at 47 and 52 for a DOE discussion of salt and alternative disposal media.

structing the Repository) planned to have an operational facility on line by 1985. CERCDC questioned whether this date would be met. Tr. 545. Testimony in this proceeding indicated that while it is still possible to meet that 1985 date, it is more likely that the actual operational date will be somewhat later than 1985. The Deutch Report, released in March of this year, concludes that it is likely that the Repository will be ready in 1988, not 1985. Deutch Report at 12.

This delay is not significant. All testimony indicated that the facility will be built and that development of this facility is a matter of the highest priority to both DOE and NRC. Further, as pointed out by the Staff, the policy of geologic disposal has been reaffirmed by both President Ford in October 1976 and President Carter in April 1977. While the operation date might slip by a few years, a Repository will become available within a reasonable time frame. The required additional temporary storage of Spent Fuel and HLW will not produce significant environmental or safety impacts. Actually, if the temporary storage time exceeds ten years the environmental impacts associated with geologic storage would decrease. NRC/FRA to CERCDC/FRQ VII.2. Thus, any slight delay that might occur in the commencement of commercial operation of the Repository does not alter the conclusions reached in NUREG-0116 or NUREG-0216. This conclusion was documented by the Staff noting that the values in Table S-3 will not be affected by a change in the time table unless the delay exceeds ten years (*i.e.*, the Repository is not on line by 1995). NRC/FRA to OH, WI, NY/FRQ 6; NRC/FRA to CERCDC/FRQ I.1; *see also*, CommEd, TVA, BG&E/FRA to CERCDC/FRQ III-5.

The disposal of I-129 was another area reviewed during this proceeding. The treatment of I-129 varies according to which of the two waste disposal alternatives is being studied. If there is no reprocessing, the Staff postulates that all of the I-129 in Spent Fuel is released into the

atmosphere shortly before the Spent Fuel is emplaced in the Repository. On the other hand, if there is reprocessing, the I-129 is taken out of the off-gas, solidified, and then placed in the Repository. Since it is in solidified form, it is assumed that it is not released prior to backfilling. Tr. 601. A question was asked about the impact from this storage of I-129. This recognizes that I-129 migrates at a more rapid rate than other radionuclides and is not held up by ion exchange. Tr. 823. This characteristic favoring migration, however, is counter-balanced by two other considerations. The first is that, since I-129 is separated out at the reprocessing stage, it can be stored in a separate area of the Repository. Second, the amounts of I-129 involved are quite small and thus are therefore susceptible to back-up protective devices at very little cost. Tr. 824.

The storage and disposal of the salt that is removed during the construction of a Repository was another area reviewed during this proceeding.[17] The amount of salt involved depends both on the disposal mode chosen and the characteristics of the individual site. NRC/FRA to CERCDC/FRQ V.G.2. If a stowaway mode is selected (*i.e.*, the material stored there will be retrievable for a number of years), the volume of salt that must be stored or disposed of increases. Various disposal options for the salt do exist. For example, the salt could be sold, disposed of in an ocean, or used as backfill for abandoned mines. Tr. 665; NUREG-0116 p. 4-81. In any event, there has been no affirmative demonstration that the environmental effects from storage of mined salt are significant. Further, when an actual site is being reviewed by the NRC for a license, these matters will be considered in whatever detail is necessary to ensure that the anticipated environmental effects pose no unacceptable risks. Tr. 667-68.

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[17] *See* NRC/FRA to NRDC/FRQ at NRC 7-126.

During the course of oral hearings, the Staff submitted SAND 77-1816. The Staff contracted for this report because it felt that it needed a more thorough analysis of the thermal effects of plutonium in the Repository. This document changed the land area commitment required for the permanent disposal of the involved wastes. Also, because the study indicates that a Repository can serve fewer reactors, changes in a few other values were made (*e.g.*, sulphur dioxide emissions from diesel fuel). Tr. 491. Under this new analysis the basic heat load for solidified HLW (with Pu) is now anticipated to be 106 kilowatts per acre rather than the previously projected 150 kilowatts per acre. A careful review of this information supports the Staff's conclusion that these changes are indeed "minor". Tr. 492. Additionally, these changes do not reflect on the technological feasibility of the model facility. The only effect of these changes is to limit somewhat the amount of waste that can be stored in a single Repository. Further, this testimony demonstrates that the Staff is fulfilling its role to provide updated information as it becomes available. This supports our general conclusion that when a Repository is licensed by NRC, it will be designed in an environmentally acceptable manner.

One final area involving the Repository reviewed in this proceeding concerned the socio-economic impacts associated with the construction and operation of a Repository. The general conclusion from the Staff's study of this area and the testimony offered by all participants is that the kinds of socio-economic impacts from a Repository are comparable to those related to a LWR. Tr. 670. Certainly the construction and operation of any project, including a Repository, will cause some socio-economic impacts. Further, the smaller the community where the Repository is placed, the greater the potential relative socio-economic impact. It is projected that it will take approximately five years to build a Repository and that

the peak number of workers would not be present for approximately another five years. Tr. 672. This time period makes it possible to develop realistic plans to manage and control these impacts. Tr. 678. Testimony in the proceeding also indicated that there are populations that are hospitable to the location of waste disposal sites. Tr. 679. This support is based on the pragmatic realization that these facilities are a source of employment which produce economic benefits for the surrounding community which outweigh any attendant risks or other negative socio-economic impacts. Tr. 687-88. Further testimony supporting this conclusion was provided by Dr. Bartlett, mayor *pro tem* of Richland, Washington. Tr. 684-89. Since the socio-economic impacts from a LWR and a Repository are similar, his comments on the Hanford experience are relevant. He also concluded that the socio-economic impacts on the affected communities from these projects were essentially positive. Tr. 687.

This proceeding developed a comprehensive record on the technological feasibility of a Repository, the potential problems that might be associated with a Repository and the significance of these problems. The record establishes that a Repository is technologically feasible and that the probability of accidents occurring (either natural or man-caused) are as low as—or lower than—that discussed in NUREG-0116. In most areas, the Staff's overall conservative approach has resulted in considerably overstated descriptions of potential environmental impacts. For instance, this conservatism is illustrated by the Staff *not* considering the beneficial impact of multiple barriers preventing waste from escaping.

This proceeding also revealed two areas where the environmental impacts from the Staff's model required minor changes. The first is in the thermal load requirement. SAND 77-1816 suggests that the model facility will have to reduce somewhat the amount of waste per unit area. This change, however, is quite minor and does

not affect the conclusion that the Repository is technologically feasible and its environmental cost is small. The second area where some slight modifications might be necessary is in measuring the environmental impact from storing salt that is removed during the construction of the Repository; the probable impact from this storage is small. It will not result in any additional radiation exposure or other significant problems.

In conclusion, the Staff's model is technically feasible. The projected impacts, with the exception of the requirement for slightly more land for the Repository, are no greater and in fact probably less than those depicted in NUREG-0116 and NUREG-0216, and thus support the continued validity of the amended S-3 values.

[PORTION OF REPORT OF THE HEARING BOARD TO THE NUCLEAR REGULATORY COMMISSION REGARDING ENVIRONMENTAL EFFECTS OF URANIUM FUEL CYCLE, DOCKET NO. RM-50-3 (August 31, 1978) (PART 2.II)*]

ATTACHMENT 1

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

HEARING BOARD

Michael L. Glaser, Chairman
Dr. John H. Buck
R. Beecher Briggs

Docket No. RM 50-3

IN THE MATTER OF

AMENDMENT OF 10 CFR PART 51
LICENSING OF PRODUCTION AND
UTILIZATION FACILITIES

(Environmental Effects of the
Uranium Fuel Cycle)

REPORT OF THE HEARING BOARD TO THE NUCLEAR REGULATORY COMMISSION REGARDING ENVIRONMENTAL EFFECTS OF URANIUM FUEL CYCLE, DOCKET NO. RM 50-3

AUGUST 31, 1978

[* For Part 2.II, see Certified Index of the Administrative Record in Docket Nos. 79-2110 and 79-2131 at Vol. 32, Doc. No. 1.]

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A. *Staff Testimony*

1. *General Criteria*

Testimony on high level waste (HLW) disposal covered both the no-recycle and the uranium-only recycle options. In the no-recycle option the high level waste is composed of complete fuel elements (which includes the normally defined high level waste (10 C.F.R. § 50 App. F) plus plutonium and other transuranium products). In a uranium-only recycle the uranium is returned to the fuel cycle leaving plutonium and other long lived radioactive isotopes as waste material. At the end of the normal reprocessing procedure the high level wastes are in liquid form but 10 C.F.R. § 50 Appendix F requires these wastes to be solidified before shipment. Therefore, for the purposes of the discussion on waste disposal, it is assumed that the waste has been solidified at the reprocessing plant prior to disposal. See *infra* p. 44.

In its assessment of the environmental impacts of permanent disposal of high level wastes the staff utilized a model based on geologic disposal.[157] (Generally applicable to either salt bed or hard rock disposal.) In a discussion with the Hearing Board, the staff witnesses pointed out that the Department of Energy (DOE) is responsible for selecting the method of disposal and the disposal site. Tr. 573-586. While DOE has made it clear that they presently favor geologic disposal, no site has yet been selected. When such sites are selected they are subject to licensing review by NRC and their indi-

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[157] In answers to questions by the States of Ohio, Wisconsin and New York the staff pointed out that in the past HLW have been disposed of by various countries in deep ocean water or inactive wells. This practice is no longer used. Several countries (*e.g.*, Canada, Netherlands, Belgium, France, Germany) have programs to develop either salt dome or crystalline rock depositories.

vidual characteristics must be such that they meet the NRC licensing criteria. The staff under present organizational responsibilities must not be in the position of prejudging any particular site before DOE presents its application. On this basis staff witness Hewitt stated that the staff site suitability criteria

> are really a series of factors that we think have to be considered in determining whether or not a site is suitable. There aren't any exact numerical type parameters in the criteria, for the simple reason that a balance has to be made on each individual site, in order to see that the environmental and radiological objectives are met. In other words, it wouldn't be possible or it wouldn't be reasonable to say that a salt bed has to be X meters thick, or so many kilometers away from a body of water, because those factors are really determined on how the hydrogeological system acts, what the gradients are, what the permeabilities are, what the actinide absorption factors are.
>
> So what we have tried to do here is to give a series of factors that have to be considered, so we can have reasonable assurance that the radiological performance objectives we establish for a repository would be met by the repository.

This series of criteria may be summarized as follows:

a. The repository site must be owned by the United States Government (including all mineral and exploration rights so that the site can be isolated from other human activity).

b. There must be "a multiple set of barriers to waste migration." Salt of course would be one barrier if a salt bed is chosen. The uniformity of geologic formations and the hydrology of the area would be of extreme importance as well as any chemical reactions which would effect isotope migration.

c. The site should be in a seismically stable area.

d. The likelihood that subterranean construction and the heat produced by the stored materials will cause major disturbances of the overburden must be small. This is necessary to assure that migration of waste from the repository into ground water that might be used for drinking or food production would be precluded.

e. The site should not unnecessarily deprive society of valuable resources.

f. If several sites are available the one chosen should be based on minimization of risk to the public not only from the site itself but transportation to the site.

g. Preferably the site should be such that long term monitoring and surveillance is not necessary.

These general criteria appear to be compatible with what is known about the present DOE site selection criteria.

Before selecting its disposal site model the staff considered such alternatives as rocket ejection of the wastes, transmutation of the long life radioactive isotopes to other nuclei by nuclear bombardment, ice sheet isolation, seabed isolation and various forms of geologic disposal. There was no serious suggestion by any party that more than salt bed or hard rock geological disposal should be considered.

2. *The Model HLW Disposal Facility*

The staff's model HLW disposal facility is discussed in the staff's initial testimony. NUREG-0116, pp. 4-71 to 4-95. It consists of a surface land area totaling some 18,000 acres of which the central 2000 acres would be over the actual burial zone. The waste material would be buried at depths of from 1000 to 4000 feet. Such a

repository is estimated to be capable of handling the waste from 4000 RRY/30 yr. or for the lifetime of 133 reference reactors.

The surface structures, shaft to the mine level and transportation equipment in the mine could be designed to handle either the solidified material from the uranium reprocessing plants (if such plants are in operation) or packaged fuel elements directly from reactor or regional storage pools. The mine itself would use the conventional room and pillar excavation. High level waste material will be embedded in glass cylinders at the reprocessing plant and placed in sealed stainless steel canisters for insertion into holes drilled in the floor of the mine. Plutonium will be reduced to powder form before encasement and burial. TRU wastes will normally be placed in sand or cement filled containers. See Part 2, I.A., *infra*.

Spent fuel assemblies would also be enclosed in larger sealed canisters, probably helium-filled (for better cooling), which would also be inserted in the floor of the mine. In either case, the placement of the waste is governed by the amount of heat given off by the canisters. The staff's present placement criteria limit heat loading to a maximum of 150 kw/acre. NUREG-0116, p. 4-114.

In its discussion of the salt mine model the staff recognizes that digging a cavern into a salt mine and placing heavy, heat producing materials on and into the salt floor may cause some of the following interactions:

a. Flow of brine pockets toward the heat source, eventually possibly producing a briny slush surrounding some of the hot canisters.

b. Gamma radiation of the brine may produce corrosive chemicals which may add to the brine corrosion of the stainless steel canisters and eventually lead to leaching of the glass in which reprocessing wastes are buried.

c. Similar corrosion will occur in the canisters around the fuel assemblies and thus expose the cladding of fuel elements and eventually the fuel pellets to the brine.

d. Heated salt tends to become fluid because of brine migration toward the heat source and may result in the fuel assembly packages sinking into the floor or tipping over, so that care must be taken in placement to avoid any possibility of creating criticality by having several assemblies come together.

The staff points out, however, that many of these problems are site specific. Some salt mixtures are better than others. Obviously the lower the brine content of the salt the better. In this connection the staff points to experiments by Oak Ridge National Laboratory (ORNL) in the Lyons, Kansas, salt mine as part of Project Salt Vault. In those experiments packaged spent fuel assemblies were successfully emplaced in the mine. See NUREG-0116, p. 4-113. This experiment lasted about 19 months. Emplacement sleeves showed no sign of damage at the end of that period. Tr. 572.

The staff's calculation of the environmental impacts of the geologic repository was based on the conclusion that radiological releases would occur only during the time that waste was being placed in the repository. The staff assumed that the only significant radioactive releases from the repository would be in the gaseous effluent. This effluent would contain all the gaseous fission products from the spent fuel and any gases released by other wastes. It would also contain small amounts of fission products and TRU nuclides that are released into the air and pass through the HEPA filters in the ventilation system.

The staff assumed that no radioactivity would be released after the repository was filled and sealed. Although the canisters would corrode and release their

contents to the salt, the salt and the surrounding media would isolate the radioactivity. Studies were made of the impact of leaching radioactivity from the HLW at a rate of 0.3 percent/yr and transporting it through soil columns to surface waters.

> The results of the study showed that for reasonable storage conditions the potential incremental radiation doses would be of the same order as, or less than, doses from natural sources . . . ."

NUREG-0116, pp. 4-80, 4-89, 4-93; Tr. 600-604.

3. *Variations in Salt Mine Model with Type of Fuel Cycle (No recycle or uranium recycle)*

In its testimony the staff discussed in some detail the variations in their model which must be assumed depending on whether no recycle or uranium only recycle is utilized. This testimony was amplified in the staff's answers to the questions of other parties and the Hearing Board.

In the uranium-only recycle the HLW, TRU wastes and plutonium must be placed in the disposal facility. Until recently it had been assumed that the bulk of the plutonium (98.5 to 99%) would be recycled as useful fuel with only the chemical process losses (1.0 to 1.5%) being included in either the HLW or the TRU wastes.

Plutonium as a waste can be handled in either of two ways: (a) as part of the HLW or (b) processed one more step and separated from the HLW in the form of highly radioactive oxide power. Under the first method the plutonium would be a portion of the liquid HLW which would be initially stored in tanks then solidified in glass and placed in stainless steel canisters for burial. The staff admits that this method has had very little study since the possibility of such disposal had not been considered until recently. Using the second method the plutonium oxide powder would be encased in heavy stain-

less steel cylinders for insertion in the mine floor. In either case, the disposal facility must be designed to hold approximately 100 times more plutonium than had previously been considered on the basis of the complete reprocessing option. NRC/FRA Questions p. 1-140.

Under the no-recycle option used fuel assemblies, after cooling for 10 to 25[158] years in water storage pools, would be enclosed in large canisters for placement in the salt mine floor. In response to a question from CERCDC the staff listed the following items which must be considered when burying spent fuel in a salt mine initially designed for solidified HLW.

a. In the high level wastes most of the uranium, plutonium and fission product gases present in spent fuel are removed during reprocessing;

b. the volume of spent fuel (per metric ton of heavy metal of reactor fuel) is larger than high-level waste;

c. the total time integrated heat output of spent fuel (per metric ton of heavy metal) is larger than that of high level waste;

d. the leach rate of fission products and actinides from spent fuel may be different than high level wastes, and

e. the possibility of forming a critical assembly in the repository must be considered because of the presence of plutonium and uranium in spent fuel.

All of the above items must be considered in the design. The staff notes that one important effect is that a "larger repository area would be required for spent fuel than for the high level wastes * * * because of the increased

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[158] Staff model actually assumes at least a 10-year cooling period. NUREG-0116, p. 4-107.

heat output of the spent fuel and to allow for movement of the different size waste canisters." *Id.* at 1-140, 141. Additonally, due to the longer (15' vs. 10'—see Tr. 554) canisters required for the spent fuel elements the mine must be higher to accommodate these canisters.

In answer to questions by Wisconsin and Ohio, the staff also pointed out that there will be ten times as many canisters required for spent fuel disposal per RRY than would be required for disposal of HLW after reprocessing. *Id.* at p. 2-24.

B. *Comments on Staff Model*

Comments on the staff's model geologic disposal facility were received from several of the parties. The most detailed of these comments came from the United States Geologic Survey (USGS) both in written testimony[159] and answers to questions during the proceeding.

1. The thrust of the USGS initial testimony was that while it was working with the Department of Energy (DOE) to establish detailed geologic criteria for repository sites it questions "whether in the absence of final criteria a definitive assessment of such (environmental) impacts can be made." In their oral testimony, USGS witnesses George D. DeBuchananne and Noel J. Trask made it clear that their primary concerns are (1) the continuing stability of the salt bed after intrusion by man and (2) placement of heat emitting wastes in the salt. Tr. 702-708.

With respect to man's intrusion into the salt mine they noted that the Lyons, Kansas mine had been abandoned as a long term repository because its integrity was doubtful due to an unknown number of bore holes which earlier had been drilled into it in search of oil. Tr. 704-

[159] Statement of George D. DeBuchananne, Chief, Office of Radiohydrology, Water Resources Division, U.S. Geological Survey, October 3, 1977.

05. Even with a controlled number of shafts they felt that sealing of such openings against water intrusion for a long period of time was an unknown technique. This may be particularly true for access shafts large enough for the elevators to place equipment and waste canisters into the mine.

The most serious problem foreseen by USGS was the stability of the salt floor and the salt backfill around the canisters. They stated that brine in the salt would tend to migrate "from a relative [*sic*] small area, 30 centimeters perhaps" toward the source of heat. (Tr. 724). It would therefore be necessary to have a low level of brine occlusions in the salt to begin with. However, long term ventilation of the mine might supply water to the salt (the salt acting as a dessicant) producing a continuous supply of brine. Tr. 724. Although the witness did not believe that any weakening of the salt support columns would occur (Tr. 726), they [*sic*] envisioned the possibility of weakening salt around the canisters which could allow them to shift or tip over. In any case, the witness concluded that no problem should occur "if the temperature of the waste were 100°C or less" above the ambient temperature of the mine. He suggested that this be achieved by storing the waste above ground for 30 or 40 years. Tr. 732-734.

In connection with the heating problem in salt Dr. DeBuchananne mentioned the use of anhydrite beds.[160] In this material, according to the witness, brine tends to migrate away from a heat source and would therefore not produce the weakening effect around the canisters that occurs in salt beds. He noted that at the New Mexico site which USGS is investigating for DOE, there appears to be a few hundred feet of anhydrite on top of the salt bed which is several thousand feet in depth. Tr. 711-12. Dr. DeBuchananne emphasized that use of such beds is a

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[160] Anhydrites ($CaSO_4$) is often deposited on top of normal salt beds to depths of up to a few hundred feet.

recent concept and there may be other stability problems such as brittle cracking that may prohibit their use.

The USGS witnesses were also concerned that the ambient mine temperature might rise enough to cause sufficient expansion of the overlying rock to crack it. This possibility is being looked at by other DOE contractors, but not by USGS.[161]

The USGS investigation is still underway. No specific site has yet been investigated sufficiently to be sure that the witnesses [*sic*] questions are answered. They also recognize that their research is concerned only with the salt and that the waste containment canisters, the rock formations surrounding the salt mine and the hydrology of those formations form a multiple barrier situation independent of the salt mine itself. Tr. 171.

Despite their "research" concerns the USGS witnesses, in answer to Hearing Board questions, stated that "we would agree that the concept of geologic disposal is a valid concept" (Tr. 728) and that finding repositories that will give the low release rates estimated by the staff is possible.

In response to Board questions the staff stated that during the 19 month Lyon experiments (Project Salt Vault)

> the heat density in Project Salt Vault was higher than one would anticipate for a half metric ton of spent fuel irradiated to 33,000 megawatt days * * *. So Project Salt Vault densities were more than would be—than to be expected with spent fuel disposal, somewhat lower than that anticipated for high level waste disposal, but in the same ball park, certainly transferable data."

Tr. 571-572

The fuel elements in the Salt Vault experiment were stored for some 18 months and were retrievable at the

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[161] This issue was admittedly outside the witnesses' expertise.

end of the period with no apparent damage to either the canister or the salt bed surrounding the containment hole. In other words, there was no sign of brine intrusion.

2. In general the comments of CERCDC, Sierra Club, NRDC and Wisconsin and Ohio emphasize the uncertainties of the staff model concerning the actual release of radioactive isotopes from the salt mine disposal site. However, as discussed below, witnesses had varying points of view on the staff's model.

a. CERCDC witness Anderson [162] believes that the staff model should have included an analysis of other geologic disposal methods than the salt beds and that the results of the disposal method with the most severe impact should have been used for conservatism. Additionally, the witness believes that it is a serious error to assume that plutonium must be disposed of irretrievably. At the very least, in his opinion, another analysis should have been made on the assumption that plutonium might be needed in the future. Similarly, Mr. Anderson believes that the staff should have considered "the option of storing spent fuel in a retrievable manner, so that at a later date, if policy or economic considerations changed, it could be reprocessed for its uranium and/or plutonium content. If necessary such temporary retrievable storage can be accomplished at a spent unreprocessed fuel facility (SURFF) which is being considered by DOE.

b. On the other hand, witness David A. Deese [163] for the States of Ohio and Wisconsin referred to the technical problems encountered at the West German ASSE salt mine repository. These were mainly brine seepage into the mine and creep of the salt dome. He believes that

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[162] Statement of Robert N. Anderson on Behalf of the California Energy Resources Conservation and Development Commission, Oct. 3, 1977, pp. 27-32.

[163] Statement of David A. Deese on behalf of the States of Wisconsin and Ohio, Oct. 3, 1977, pp. 13-17.

there is insufficient test data to conclude that the Carlsbad, New Mexico, mine will be completely satisfactory and, like the USGS, is concerned about the effects of human intrusion, brine and heat on the salt.

c. Sierra Club witness Marvin Resnikoff[164] does not agree with the staff and industry that reprocessing will reduce the volume of waste material that must be managed. He claims that the addition of chemicals in reprocessing will increase volume. It is unclear in his statement just how much of this additional volume is low level waste. While the witness agrees that heat output is the largest problem for the disposal, his analysis treats no-recycle and plutonium-plus-uranium recycle but does not treat the situation of uranium-only recycle that is of interest in this proceeding. *Id.* Appendix C, Tables 1, 2, 3.

d. While NRDC did not present direct evidence on the salt bed disposal their concluding statement appears to indicate agreement with the USGS concerns.

3. Testimony by Baltimore Gas and Electric, Commonwealth Edison, *et al.*, Tennessee Valley Authority and Pacific Legal Foundation all expressed general approval of the staff's geologic disposal model.[165] All expressed the opinion that the staff's assumptions were overly conservative. In particular, it was noted that geologic disposal creates a series of barriers to the escape of radioactive isotopes that are underestimated by the staff. In summary, the following points were made by witnesses for these parties concerning the staff's over-conservatism.

a. For spent fuel buried in stainless steel canisters, the staff assumed the integrity of the canisters, fuel elements and fuel pellets would only last long enough to back fill [*sic*] the areas of the mine in which they were located. This

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[164] Appendix C to Statement of Marvin Resnikoff, Sep. 30, 1977.

[165] See Initial Testimonies presented by BG&E, *et al.*, Commonwealth Edison, *et al.*, TVA; PLF.

means that the stainless steel canisters, fuel cladding and pellets would corrode in less than 25 years and under the staff assumption would release all the gaseous radioactivity to the atmosphere before the mine is sealed. See p. 75 *infra*.

b. For the HLW enclosed in glass, the staff assumed that the stainless steel canisters would corrode rapidly and the glass would be leached away with a half-life of approximately 200 years. Witnesses for PLF mentioned several experiments which indicate that the glass cylinders have a half-life of at least one million years (Tr. 767-769). The staff itself in answer to a question raised by NRDC stated:

> All materials have some solubility or leachability in water. The rate of leaching of a glass is dependent on many things, including: glass composition, particle state, temperature of the water, pH, chemical contents, flow rate of water, length of reaction time, and element measured. With the wide range possible, waste glasses can have reported leach rates from 10^{-3} to 10^{-8} grams/cm^2/day.
>
> Since leaching is a surface area dependent value, large scale tests are not normally used to determine leach rates. However, one semi-large test has been conducted in Canada with blocks of HLW in ground waters. Leach rates after 15 years burial are continuing to decrease and are about 10^5 times lower than leach rates determined in the laboratory.

NRC/FRA, p. 7-93.

c. The staff and USGS assumed that any water leakage into the mine would result in instantaneous removal of radioactive material from the mine. Witnesses for the utilities and PLF note that that assumption ignores the tremendous volumes of salt involved and points out that the staff itself stated in answer to a Board question:

Q. Well, the USGS says that one has to assume that the salt mine is going to get flooded at some time. Other people have expressed concerns about water getting access to the salt and dissolving out fission products or dissolving out plutonium.

So one would like to know, are there places in nature where salt deposits have existed and where water has gotten access to the salt deposits and dissolved out the material, or are there not situations like this?

A. (Witness Bishop) There certainly are such situations. If we can use a concrete example, in southeast New Mexico, it is quite well known that the salt fronts at the edges of that major salt bed in the Permian Basin are being dissolved away at a rate which, although it is not in my head, it is in a number of reports, from Sandia Laboratory and the old Oak Ridge National Laboratory reports—I am reminded that the units are sort of a mile or so per million years.

Tr. 610-11.

PLF witness, Dr. Cohen noted that

> * * * if all the ground water now flowing through all the aquifers above the salt formation (at the New Mexico site) were diverted to flow through the salt formation, it would take 50,000 years to dissolve away the salt enclosing one year's waste.

Tr. 819.

4. The staff has assumed that once out of the salt mine itself the radioactive isotopes will be transported through the surrounding media by underground water. Witnesses for PLF called atttention to the OKLO phenomenon in Africa to show that heavy elements are not transported long distances by water.

The OKLO phenomenon was discovered in a uranium mine near Gabon, Africa, where a natural chain reaction was found to have occurred approximately 1.8 billion years ago. The reaction required a unique set of circumstances to supply the right combination of uranium isotopes and water and it apparently lasted somewhat intermittently for thousands of years. The reaction on the basis of tests at the mine generated several tons of fission products and plutonium. Tests at the mine indicate that the fission products moved very little and none of the plutonium moved any detectable amount. PLF Initial Statement by Marc W. Goldsmith, October 3, 1977.

PLF makes the point that even if the fission products and plutonium are washed out of the salt mine the OKLO data indicates their movement in the geologic formations around the salt bed would be minimal even with high water flow.[166] Tr. 772-774.

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[166] The State of Wisconsin and NRDC question the applicability of OKLO phenomenon to waste disposal in salt formations.

**[BALTIMORE GAS & ELECTRIC, *et al.*,
LETTER OF JANUARY 23, 1979 AND ENCLOSURE *]**

LAW OFFICES
HUNTON & WILLIAMS
1730 Pennsylvania Ave. N.W. Suite 1060
P.O. Box 19230
Washington, D.C. 20036
Telephone (202) 393-7400

January 23, 1979

Richmond, Va. Office
707 East Main Street
P.O. Box 1535 23212
Telephone (804) 788-8200
File No. 28263.000004

Dr. Joseph M. Hendrie, Chairman
Mr. Victor Gilinsky, Commissioner
Mr. Richard T. Kennedy, Commissioner
Mr. Peter A. Bradford, Commissioner
Dr. John F. Ahearne, Commissioner
United States Nuclear Regulatory Commission
Washington, D.C. 20555

Docket No. RM-50-3

Gentlemen:

Baltimore Gas and Electric Company, *et al.* appreciate this opportunity to present brief final remarks in the "Table S-3" proceeding. The occasion for them arose from the Commission's granting to the Natural Resources Defense Council, another participant in this proceeding,

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[* See Certified Index of the Administrative Record in Docket Nos. 79-2110 and 79-2131 at Vol. 34, Doc. No. 2.]

the opportunity to deliver rebuttal, without prior reservation of time for it, at the end of the scheduled oral presentations last Friday, January 19, (Tr. 176-77). The attached statement, sponsored by Drs. Joseph A. Lieberman and Walton A. Rodger, two of this Group's expert witnesses, is responsive to that unanticipated rebuttal and represents what these witnesses would have stated in person if they had been present at the time.*

With respect to the significance of documents which have been released since the close of this proceeding's evidentiary record (Tr. 176-77), the statement explains why none of them affects the validity of the Staff's bases and assumptions for a model waste repository. With respect to the related question of whether the Staff has estimated a "worst case" for a waste repository release (cf. Tr. 165-66, 180-81), the statement reaffirms Drs. Lieberman's and Rodger's assessment that the impact of a meteorite would present a "worst case" scenario. The statement also shows that Claiborne and Gera, authors of the report from which the calculated accident consequences reported in NUREG-0116 were derived, have since concluded that their report overstates calculated doses by a factor of 10,000 (10^4). The result is that the potential dose from a worst case repository release, as depicted in NUREG-0116, would similarly appear to be overstated by a factor of 10,000.

Once again, we appreciate the Commission's consideration in affording us this opportunity to round out the record.

Sincerely yours,

/s/ Donald P. Irwin
DONALD P. IRWIN
Attorney for Baltimore Gas
and Electric Company, *et al.*

Enclosure

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* Not expecting the rebuttal statement in question, since opportunity for it had not been timely requested, Drs. Lieberman and Rodger had left the room shortly before.

CONCLUDING REMARKS OF DRS. JOSEPH A. LIEBERMAN AND WALTON A. RODGER

January 23, 1979

During the course of the proceedings on the S-3 rulemaking, various reports * have been released by Federal agencies or groups which purport to identify uncertainties and gaps in the knowledge base supporting the viability of the concept of disposal of high-level wastes in geologic repositories. Our review of these reports does not affect our conclusion ** that the technology exists to permit the location, design construction and operation of a safe and environmentally acceptable geologic repository. It is also our judgment that the observations and conclusions of these reports do not significantly affect the adequacy of the impact estimates in the Table S-3 recommended by the Board.

It should be pointed out that all of the referenced reports were available to members of the IRG and that, indeed, the Federal agencies involved, USGS and EPA,

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* TID-28817 (Draft) Report to the President by the Interagency Review Group on Nuclear Waste Management, October, 1978.

TID-28818 (Draft) Subgroup Report on Alternative Technology Strategies for the Isolation of Nuclear Waste, October, 1978.

US Geological Survey Circular 779, Geological Disposal of High-level Radioactive Wastes—Earth Science Perspective, 1978.

EPA/520/4-78-004 State of Knowledge Regarding Potential Transport of High-level Radioactive Waste from Deep Continental Repositories—Report of an Ad Hoc Panel of Earth Scientists, EPA, April 1978.

Solidification of High-level Radioactive Wastes, National Research Council, pre-publication copy August, 1978.

** This conclusion, and its bases, are outlined in the Joint Initial Statement of Baltimore Gas and Electric Company, *et al.*, Commonwealth Edison Company, *et al.* and the Tennessee Valley Authority in this proceeding, at Chapters III and VI.

participated in the development of the IRG draft report. In this context, it is worth noting that the IRG draft report states, on page 3 of the Introduction, that:

> "Confidence has now increased to the point where the majority of informed technical opinion holds that the capability now exists to characterize and evaluate media in a number of geologic environments for possible use as repositories built with conventional mining technology and that successful isolation of radioactive wastes from the biosphere appears feasible for periods of thousands of years."

The IPG draft report also states on page vii of the Summary, under Technical Findings and Conclusions, that:

> "Overall scientific and technological knowledge is adequate to proceed with region selection and site characterization, despite the limitations in our current knowledge and modeling capability. Successful isolation of radioactive wastes from the biosphere appears technically feasible for periods of thousands of years provided that the systems view is utilized vigorously."

Although other statements in the IRG report have been used out of context to blur the clarity of the findings noted above, we believe these findings support the viability and validity of the bases and assumptions utilized by the NRC Staff in arriving at their estimates of waste management impacts.

With respect to "uncertainties and gaps" in knowledge, an IRG Subgroup report, TID-28818, states on pages vi of Appendix A: *

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* The title of Appendix A is: "Isolation of Radioactive Wastes in Geologic Repositories: Status of Scientific and Technical Knowledge."

> "Some uncertainties can be bounded and compensated for and, therefore, need not be resolved completely before selecting a site for constructing a repository. In addition, other uncertainties will be resolved during repository construction. Although reliance on appropriate engineering practices and multiple barriers can compensate for a lack of total knowledge and predicative capability, some residual uncertainty will always remain."

Some of the alleged uncertainties simply reflect the need for site-specific data and information which is required for repository site evaluation and selection and which would provide the bases for detailed engineering design of a site-specific repository. Other "uncertainties or gaps" attributed to salt as a repository medium are more in the nature of hypotheses than proven fact. For example, data exist from field and laboratory tests (Project Salt Vault, Sandia and ORNL) that indicate that brine migration to emplaced waste may not take place under actual repository operating conditions, and that even if it does, it would not be sufficient in quantity to establish a hydraulic pathway for return of the waste to the biosphere. Moreover, factors that control potential brine migration and its possible interaction with emplaced waste are subject to control through repository system design and operational control. It is also fairly clear that the hydrothermal conditions which are alluded to in the USGS Circular 779, and which the National Research Council draft report argues could cause rapid deterioration of glassified waste, would not, in fact, exist in an actual repository and, furthermore, are subject to repository design and operational control. We continue to be convinced that salt represents a technically viable medium for a nuclear waste repository. Other geologic formations or media are likely also to be suitable. The USGS circular, while it notes in the Foreword at page III that "the earth science prob-

lems associated with disposal of radioactive wastes are not simple nor are they completely understood," also states that ". . . the authors are confident that acceptable geologic repositories can be constructed. . . ." *Id.*

We have the following additional comments regarding the Staff's remarks with respect to inclusion in the final S-3 rule of the environmental impacts resulting from a breach of the permanent repository and a "worst case" analysis applicable to waste disposal impacts.

We do not believe that the environmental effects of a breach of the permanent repository need be specifically included in Table S-3 since the risk of such potential environmental effects is vanishingly small. We would note, however, that consideration of a breach of the repository is contained in the underlying record in the development of Table S-3 (in GESMO at page IV H-49, NUREG-0002, Vol. 3 and in NUREG-0116 at pp. 4-89 through 4-99, and specifically at Tables 4.23 and 4.24). It is there concluded that while a surface burst of a 50-megaton nuclear weapon could not breach the repository, it is conceivable that the direct impact of a sufficiently large meteorite might do so. The probability of such an event is estimated to be on the order of 10^{-13} per year (once in 10 trillion years). Two consequences of such a breach were considered. The first was the ejection of waste into the upper atmosphere so that it was dispersed globally. The consequences of such dispersion were found to be minor. The second was the contamination of the area surrounding the site. The potential consequences of this are given in Tables 4.23 and 4.24 of NUREG-0116, referenced above.

We would note for the record that these two tables overstate the potential doses by a factor of 10,000 because of an apparent computational error. We called this error to the attention of H. C. Claiborne, one of the authors of

the report on which the tables were based,* and he has acknowledged that, indeed, the error ** is included in the report's tables as carried over to NUREG-0116.

In view of the extreme unlikelihood of such a breach in the repository in the first place and the lack of significant consequences even were such a "worst case" breach to occur, we conclude that the underlying record of this proceeding does appear to consider a "worst case" event at a high-level waste repository, that the consequences are lower by a factor of 10,000 than they are presently indicated to be, and that there is no need to include the impacts of a repository breach in the S-3 table itself.

In summary, we conclude the following:

a) a safe, environmentally acceptable waste disposal system involving emplacement of solidified wastes or spent fuel in salt or other geologic media is feasible and the NRC Staff model of this system is adequate;

b) the Staff's model and analysis of the repository system are consistent with the IRG draft report, and neither that report nor other recent documents which we have received provide any significant basis or justification for modification of the bases used by the Staff to arrive at waste management impact estimates;

c) a "worst case" analysis applicable to high-level waste disposal impacts is contained in the underlying record of this proceeding and there is no need

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* H. C. Claiborne and F. Gera, "Potential Containment Failure Mechanisms and Their Consequences at a Radioactive Waste Repository in Bedded Salt in New Mexico," ORNL-TM-4631, Oak Ridge National Laboratory, 1974.

** The error is acknowledged and explained in the attached letter from H. C. Claiborne to J. V. Muckerheyde, dated October 13, 1978.

to include these impacts in the final rule because of lack of significant consequences if such a "worst case" did materialize.

/s/ Joseph A. Lieberman
JOSEPH A. LIEBERMAN

/s/ Walton A. Rodger
WALTON A. RODGER

Attachment: Letter, H. C. Claiborne to J. V. Muckerheyde, October 13, 1978.

OAK RIDGE NATIONAL LABORATORY
Operated By
UNION CARBIDE CORPORATION
NUCLEAR DIVISION

[SEAL]

Post Office Box X
Oak Ridge, Tennessee 37830

October 13, 1978

Mr. J. B. Muckerheide
101 Valley Road
Needham, Massachusetts 02192

Dear Jim:

You and Walter Roger [*sic*] were quite right in estimating that the doses shown in Tables 5 and 6 on ORNL-TM-4839 are too high by a factor of 10^4. I have discussed this matter with John P. Witherspoon, who did the original calculations, and he concurs that they are too high by a factor of 10^4. He is not sure how the error occurred since the original calculation sheets are no longer available but it could have happened as a result of confusing $\mu Ci/m^2$ for $\mu Ci/cm^2$.

In retrospect, it is difficult to imagine that such an error could occur. A little reflection leads to the conclusion that millions of acres would be highly contaminated as the result of all the atmospheric weapons tests if those doses were correct.

It is fortunate (but embarrassing) that the error was

discovered since even the giant meteorite strike can no longer be considered a potential radiological disaster.

I hope this will suffice to set the record straight.

Sincerely,

/s/ W. C. Claiborne
W. C. CLAIBORNE
Geologic Disposal Technology Program

HCC:dd

cc: F. Gera, OECD
W. Roger [*sic*], Nuclear Safety Associates
W. C. McClain

**[NRC SECRETARY LETTER
TO NRDC OF
October 31, 1979 *]**

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

October 31, 1979

[SEAL]

Office of the Secretary

Helene Linker, Esq.
Natural Resources Defense Council, Inc.
917 15th Street, NW.
Washington, DC 20005

Dear Ms. Linker:

The Commissioners have considered your letter of August 27, 1979 requesting that the Commission supplement its order of July 27, 1979 promulgating the final uranium fuel cycle rule ("Table S-3"). You asked that the Commission direct its staff to include in the explanatory narrative now in preparation a discussion of the uncertainties in the numerical values in Table S-3 and, pending adoption of the narrative, to address these uncertainties in individual licensing proceedings.

[* This document was docketed in USNRC Rulemaking Docket No. RM-50-3 on November 2, 1979 after the preparation of the Certified Index in U.S. Court of Appeals Docket Nos. 79-2110 and 79-2131 on October 29, 1979. See *supra* p. 67. However, it was included in the J.A.S. in the court below at 1080-1081 and identified as "34 A.R. No. 16."]

As your letter observes, in promulgating the fuel cycle rule the Commission concluded that uncertainties regarding waste disposal need not be reflected explicitly in the rule. After considering the arguments in your letter the Commission remains of the same view. The Statement of Consideration accompanying the rule set forth the Commission's reasoning as follows:

> On the individual reactor licensing level, where the proceedings deal with fuel cycle issues only peripherally, the Commission sees no advantage in having licensing boards repeatedly weigh for themselves the effect of uncertainties in the selection of fuel cycle impacts for use in cost-benefit balancing. This is a generic question properly dealt with in this rulemaking as part of choosing what impact values should go into the fuel cycle rule. The Commission concludes, having noted that uncertainties exist, that for the limited purpose of the fuel cycle rule it is reasonable to base impacts on the assumption which the Commission believes the probabilities favor.

44 *Fed. Reg.* 45362, 45369 (August 2, 1979).

As this passage indicates, the Commission's decision not to include uncertainties in the fuel cycle rule rests in part on the limited and peripheral functions which the rule serves in individual reactor licensing. It must be remembered that the rule applies to a single aspect of the impact statement for an individual power reactor and is not intended to provide an environmental analysis for making a choice among alternative fuel cycle technologies. The point of the rule is to give the licensing board a generic guide for factoring into the cost-benefit balance for the reactor the relatively small contribution of fuel cycle activities. If the rule included uncertainties, as your letter advocates, the licensing board would have to judge for itself from the spectrum of possible effluent release values a particular set most likely to be representative of fuel cycle contributions to the environmental

impact of the plant. This judgment, which itself is a generic question, has been performed by the Commission through its choice of the values appearing in Table S-3. The uncertainties underlying these values are acknowledged and discussed in the Statement of Consideration accompanying the rule. The Commission believes this approach adequately discloses the uncertainties in fuel cycle impacts and in all respects meets the requirements of NEPA.

For these reasons the Commission declines to direct that uncertainties in the Table S-3 values be discussed in individual licensing proceedings. The Commission notes that the draft explanatory narrative will be made available for public comment. The Commission would appreciate receiving your comments and suggestions on it.

Sincerely,

/s/ Samuel J. Chilk
SAMUEL J. CHILK
Secretary of the Commission

GEOLOGICAL SURVEY CIRCULAR 779[*]

[SEAL]

GEOLOGIC DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES— EARTH-SCIENCE PERSPECTIVES

[SEAL]

[* This document was docketed in USNRC Rulemaking Docket No. RM-50-3 on May 25, 1978. *See* Certified Index of the Administrative Record in U.S. Court of Appeals Docket Nos. 79-2110 and 79-2131, Vol. 29, Doc. 13 (reproduced *supra* p. 104).]

Geologic Disposal of High-Level Radioactive Wastes—Earth-Science Perspectives

By J. D. Bredehoeft, A. W. England, D. B. Stewart, N. J. Trask, and I. J. Winograd

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GEOLOGICAL SURVEY CIRCULAR 779

A summary of factors and processes that must be understood for the safe containment of high-level radiactive waste

United States Department of the Interior
CECIL D. ANDRUS, *Secretary*

[SEAL]

Geological Survey
H. William Menard, *Director*

First printing 1978
Second printing 1979

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U.S. Geological Survey
1200 South Eads Street, Arlington, VA 22202

FOREWORD

Earth scientists have been concerned with the problem of disposal of radioactive wastes since 1955 when the National Academy of Sciences gathered 65 scientists in Princeton, N.J., to consider the geological, biological, physical, and chemical aspects of waste containment. Investigations during the 1950's and early 1960's examined the feasibility of disposal of liquid high-level wastes in deep geologic basins and in salt mines. Scientists since then, sponsored largely by the U.S. Atomic Energy Commission and later by the U.S Energy Research and Development Administration, carefully considered salt deposits as a repository for solidified high-level wastes. Within the past few years, in response to growing pressures for a resolution of the problem of disposing of the wastes, earth scientists at various universities and government laboratories, as well as at the U.S. Geological Survey (USGS), also began an intensive examination of the problem. As a result of this expanded examination, modified concepts of geologic disposal have evolved, and aspects of some older concepts have been questioned. Some of these changes in outlook and philosophy as perceived by USGS scientists are described in this Circular. Because the authors are confident that acceptable geologic repositories can be constructed, this paper should not be construed as an attempt to discredit the concept of geologic containment or the work done in the 1960's and early 1970's. However, the earth-science problems associated with disposal of radioactive wastes are not simple, nor are they completely understood. The many weaknesses in geologic knowledge noted in this report warrant a conservative approach to the development of geologic repositories in any medium. Increased participation in this problem by earth scientists of various disciplines appears necessary before final decisions are made

to use repositories. Basic philosophical, as well as technological, issues remain to be resolved.

/s/ William A. Radlinski
WILLIAM A. RADLINSKI
Acting Director
U.S. Geological Survey

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Geologic Disposal of High-Level Radioactive Wastes—Earth-Science Perspectives

J. D. Bredehoeft, A. W. England, D. B. Stewart, N. J. Trask, and I. J. Winograd *

INTRODUCTION

An effective solution to the problem of long-term storage of radioactive waste is essential to the expanded use of nuclear power. Radioactive waste is the inevitable byproduct of the generation of electricity by nuclear reactors or of the production of plutonium for weapons. Fuel assemblies must be removed periodically from nuclear reactors as fission products accumulate. These spent and contaminated fuel assemblies contain large concentrations of fission products such as ^{90}Sr and ^{137}Cs, which decay to innocuous levels during several hundred years, and of longer lived transuranic elements and their daughters, elements such as plutonium, americium, neptunium, and radium. These elements persist for as long as several million years.

The spent fuel from a nuclear reactor must be isolated either permanently or temporarily from the biosphere. Spent fuel can be processed chemically to recover most of the plutonium and unfissioned uranium for possible reuse. The residuum [*sic*] from this process is a highly radioactive byproduct which must also be isolated from the biosphere. This byproduct is what is usually referred to as "high-level waste." The United States does not plan

* Authors listed alphabetically.

to reprocess spent fuel chemically; thus, the immediate problem of commercial radioactive waste is one of handling, storing, and ultimately disposing of spent fuel assemblies.

Radioactive wastes from military activities are somewhat different. These wastes are mainly the residue after plutonium has been extracted from radioactive materials that have been irradiated in a reactor designed specifically to produce plutonium. Although military wastes contain many of the same fission products and transuranic elements as commercial waste and occupy significant volumes, their total radioactivity is relatively low—at present about the same as that stored in spent-fuel assemblies from commercial reactors (Nuclear Energy Policy Study Group, 1977, p. 244).

The volume of commercial radioactive waste that will accumulate during the next few decades will depend upon the growth of the nuclear-power industry and on the form of the waste. King and Baker (1976, p. 206) estimated that by the year 2000, as many as 476,000 spent fuel assemblies will be on hand if none has been reprocessed. If these spent fuel elements were to be reprocessed, the resulting solid high-level waste would occupy approximately 3,000 cubic meters (m^3) (Blomeke and Kee, 1976, p. 99), and accompanying intermediate-level wastes contaminated by transuranic elements would occupy a volume one order of magnitude larger than the volume of high-level wastes (Blomeke and Kee, 1976, p. 108).

Wastes generated by military activities, 81 million gallons in liquid and solidified form, are held in temporary storage by the U.S. Department of Energy (DOE) at Hanford, Wash., Savannah River, Ga., and Idaho Falls, Idaho (Nuclear Energy Policy Study Group, 1977, p. 250). Because of their chemistry, most of these wastes

present uniquely difficult problems in handling (Nuclear Energy Policy Study Group, 1977, p. 249).[1]

It is generally accepted that repositories in geologic media can provide the most certain safe containment of radioactive waste. DOE is developing, and intends to have licensed sometime in the 1980's, a Waste Isolation Pilot Plant (WIPP) in bedded salt near Carlsbad, N. Mex. The Nevada Test Site and the Hanford, Wash., facilities are being explored for suitable geologic repositories. Evaluations of sites in bedded salt of the Salina and Permian basins, salt domes of the gulf coast, and salt anticlines of the Paradox basin are also continuing. Reconnaissance work to assess the potential of a repository in shale or crystalline rock is underway. In the first repositories used, wastes would be retrievable for 10 to perhaps as many as 50 years.

Radioactive wastes are highly toxic. A commonly cited measure of this toxicity is afforded by a computation of the quantity of water needed to dilute high-level wastes to levels specified in the Radiation Concentration Guides (RCG, see headnote to table 1). These volumes were tabulated by Blomeke and Bond (1976); they are reproduced in table 1 and are compared with the volume of the oceans and of fresh water in lakes, rivers, and glaciers in table 2. A volume of 5.2×10^{16} m^3 of water, which is almost 4 percent of the oceanic volume (1.4×10^{18} m^3), would be needed to dilute the wastes on hand at the year 2000 to levels specified in the RCG; this volume is almost double that of fresh water in global storage in lakes, rivers, ground water, and glaciers. Even after a million years, the volume of water needed to dilute these wastes to the levels specified in the RCG is significant in terms

[1] An additional 600,000 gallons of liquid high-level waste and sludge derived from both commercial and military spent fuel are in temporary storage at West Valley, N.Y. (Nuclear Energy Policy Study Group, 1977, p. 252).

TABLE 1.—*Properties of high-level wastes to be accumulated by the year 2000 (from Blomeke and Bond, 1976, p. 87)*

[Toxicity is defined as the cubic meters of air or water that would be required to dilute the radioactive constituents to levels specified in the Radiation Concentration Guides (RCG: see colume 2 of tables I and II, U.S. Code of Federal Regulations, Title 10, Pt. 20) as the maximum allowable for unrestricted use. MCi, megacurie; kW, kilowatt]

	Accumulated by year 2000	Time elapsed following year 2000, in years			
		1,000	10,000	100,000	1,000,000
Radioactivity, MCi	158,000	63.1	24.5	4.7	1.6
Fission products	155,000	4.7	4.5	3.4	0.7
Actinides	3,400	58.4	20.0	1.3	0.9
Thermal power, kW	770,000	1,500	470	36	21
Fission products	657,000	5.3	4.9	3.1	0.2
Actinides	113,000	1,500	470	33	21
Inhalation toxicity, m^3 air	$1.2x10^{22}$	$3.4x10^{20}$	$1.4x10^{20}$	$1.0x10^{19}$	$4.4x10^{18}$
Fission products	$7.0x10^{20}$	$1.8x10^{15}$	$1.8x10^{15}$	$1.3x10^{15}$	$2.1x10^{14}$
Actinides	$1.1x10^{22}$	$3.4x10^{20}$	$1.4x10^{20}$	$1.0x10^{19}$	$4.4x10^{18}$
Ingestion toxicity m^3 water	$5.2x10^{16}$	$1.1x10^{13}$	$3.3x10^{12}$	$1.7x10^{12}$	$6.4x10^{11}$
Fission products	$5.2x10^{16}$	$1.8x10^{10}$	$1.8x10^{10}$	$1.4x10^{10}$	$2.4x10^{9}$
Actinides	$4.4x10^{14}$	$1.1x10^{13}$	$3.3x10^{12}$	$1.7x10^{12}$	$6.4x10^{11}$

TABLE 2.—*World supply and volume of annually cycled water (abbreviated from Nace, 1969)*

[Nace's (1969) data were reported in km^3x10^{-3}. We converted his data to cubic meters to permit a direct comparison with the data of table 1 ($1\ km^3 = 10^9\ m^3$)]

Source of water	Global volume (in m^3)	Percentage of total water
Oceans	$1.4x10^{18}$	97.6
Rivers (average channel storage)	$1.7x10^{12}$	0.0001
Freshwater lakes	$1.2x10^{11}$	0.0094
Saline lakes; inland seas	$1.0x10^{11}$	0.0076
Soil moisture; vadose water	$1.5x10^{14}$	0.0108
Ground water (upper 1,000 m only)	$7.0x10^{15}$	0.5060
Ice caps and glaciers	$2.6x10^{16}$	1.9250
Annual river runoff	$3.0x10^{13}$	0.0021

of water stored in individual major lakes and aquifers. Another crude measure of the potential waste hazard was provided by Cohen (1977, p. 28). He showed that the potential for millions to billions of fatal cancer doses is contained in the wastes provided by just 1 year of United States nuclear-power production if all the waste were to be ingested, an admittedly unlikely scenario. The above-cited tabulations are simplistic because they ignore the environmental pathways to man after production and burial of the wastes, yet such computations are a sobering reminder of the seriousness of the waste-disposal endeavor. Clearly, radioactive wastes constitute a major hazard. The magnitude of the associated risk depends upon the environmental pathways to man. An assessment of that risk depends upon our understanding of those pathways now and for thousands of years.

Wastes from a deep repository could be exposed to the biosphere either (1) by some geologic process such as tectonism, diapirism, or erosion that directly exposes the waste or (2) by some process that transports the wastes to the biosphere. Transport by ground water is acknowledged to be the most probable mechanism for moving the radioactive wastes the necessary distances from repository to the biosphere.

Development of acceptable waste repositories involves in the most general terms: (1) identification of sites that meet broad criteria for tectonic stability, slow ground-water movement, and long flow paths to the surface; (2) intensive subsurface exploration of such sites to determine the hydrologic and geologic conditions in and around the potential repository; (3) predictions of repository behavior based on the initial conditions and on various assumptions about the future; (4) evaluation of the risk associated with these predictions; and (5) a judgment whether these risks are acceptable. This Circular is not intended to address each of these steps in detail; we do discuss some of the key earth-science questions involved

in the first four steps. Step 5, of course, requires a political decision and is beyond a technical discussion.

The authors of this Circular are confident that the steps outlined above can be carried out in such a way that the ultimate decision on the acceptability of a given site and waste-handling procedure will have a strong scientific and technical foundation. However, some key geologic questions are unanswered, and answers are needed before the risk associated with geologic containment can be confidently evaluated. In this Circular, we discuss briefly the various media that have been considered for geologic disposal of radioactive waste and point out the need for several relatively new techniques for characterizing the rocks in the immediate vicinity of a repository. We consider a variety of possible interactions among the mined opening of the repository, the waste, the host rock, and any water that the rock may contain. Many of these interactions are not well understood, and this lack of understanding contributes considerable uncertainty to evaluations of the risk of geologic disposal of high-level waste. Because salt is being considered as a potential repository medium, we point out some geochemical uncertainties connected with its use. Knowledge of the ground-water flow path from a repository is important in providing a backup containment system if waste should leak from the repository, and we devote a section to considerations of describing and modeling such systems. In the next section, modeling and geologic prediction are discussed from the point of view of some philosophical aspects of prediction in the geosciences. A concluding section suggests research areas that we feel need emphasis. The discussion is qualitative throughout; quantitative treatment of several of the topics considered is underway in the Geological Survey and elsewhere.

Acknowledgments

The authors of this report are listed alphabetically. The sections were authored as follows: Introduction by

N. J. Trask, I. J. Winograd, and A. W. England; The repository host rocks and site characterization by A. W. England and N. J. Trask; Perturbation caused by the repository and waste by D. B. Stewart and J. D. Bredehoeft; The ground water system by J. D. Bredehoeft; Containment time frames and geologic prediction, by I. J. Winograd and N. J. Trask; and Research needs and concluding statement by N. J. Trask.

Critical and helpful reviews of this Circular were provided by Jesse Cleveland, Gary L. Dixon, Edwin B. Eckel, Leonard M. Gard, Arthur H. Lachenbruch, Walter B. Langbein, Nicholas C. Matalas, Thomas Maddock, Jr., Zell E. Peterman, John B. Robertson, Jacob Rubin, Robert Schneider, Harry W. Smedes, Frank W. Trainer, William E. Twenhofel, Leonard A. Wood, Warren W. Wood, and E-an Zen.

THE REPOSITORY HOST ROCKS AND SITE CHARACTERIZATION

Different rock types have been considered as the host rocks for radioactive-waste repositories. Rock salt received early attention because of its low porosity and permeability, its plasticity, and its high thermal conductivity (Natl. Acad. Sci., 1957). In recent years, shale, limestone, granitic rocks, and basalt have been considered (Schneider and Platt, 1974). These rock types provide low primary permeability and, in many areas, a high degree of structural stability. Parts of the Precambrian shield are known to be extremely stable (Yardley and Goldich, 1975). The clay minerals in shales have a potential for significant radionuclide sorption (Brindley, 1977), although measurements of this property are still incomplete. Another rock type having a high sorptive potential is zeolitized tuff, which is widespread in the Basin and Range province of the Western United States. The overall desirable properties of these rock units, such as thickness, depth, homogeneity, and tectonic stability,

have been discussed at length previously (ERDA, U.S. Energy Research and Devel. Adm., 1976) and are not reviewed here.

The identification of potential host rocks for radioactive-waste repositories and of broad geographical areas having generally acceptable properties is followed by more detailed studies of smaller specific areas of interest. The volume of rock that will be needed to accommodate an actual waste repository will probably be relatively small—approximately 10 km^3 (ERDA, 1976). However, that volume must be intensively explored by all appropriate methods.

Planning a waste repository, like planning subsurface mining and tunneling, requires a full understanding of the subsurface geology, but the consequences of an undetected error in planning the waste repository are more severe. Finding unexpected ground-water conduits, shear zones, fault-displaced or pinched-out beds, abandoned excavations, or variable lithology could be hazardous and costly. The discovery of such anomalies during the excavation of a nuclear-waste repository could force abandonment of the site.

Confidence that a prospective site is likely to provide adequate containment derives from an understanding of structural and lithologic features apparent at scales from a few meters to tens of kilometers. Many critical features are subtle. For example, small faults, particularly strike-slip faults, can be extremely difficult to detect and to date. Fracture systems, which could act as short-circuiting conduits for ground water, might be revealed from regional structure features clearly evident only at the scale of a Landsat image (Pickering and Jones, 1974; Drahovzal and others, 1974) or perhaps from buried structural features indicated by the distribution of soil moisture (Johnson and England, 1977). Furthermore, the necessary structural integrity and lithologic homo-

geneity cannot be assured simply through detailed surface geologic mapping and coring, particularly if the number of core holes is limited by the risk to the potential repository caused by extensive local drilling.

Techniques for remotely exploring a volume of rock are in various stages of development and should be applied to potential waste-repository sites as soon as practical. These methods are used from the surface, between boreholes, and at the head of an excavation. They include high-resolution seismic and acoustic techniques, which can detect fine-scale structural and lithologic variations (Laine and others, 1977), and electric and electromagnetic methods, which are primarily sensitive to the distribution of water (Scott and others, 1975; Daniels, 1977). Some of the most recently devised methods use short-pulse radar (Stewart and Unterberger, 1976; Watts and England, 1976) and continuous-wave interferometry (Rossiter, 1977); their use is limited to high-resistivity materials such as salt and perhaps dry crystalline rock.

The techniques cited provide a nondestructive way of characterizing the site in detail. Some of the borehole-to-borehole electrical techniques need to be further refined, but the critical need to map the original subsurface structure, lithology, and ground-water regime warrants the aggressive utilization of such techniques where appropriate.

PERTURBATIONS CAUSED BY THE REPOSITORY AND THE WASTE

The original host rock and any included water will be perturbed for substantial periods of time by the waste and by excavation of the repository. Three kinds of perturbations can be caused: (1) mechanical disturbances initiated by mining of the repository; (2) chemical disturbances caused by the introduction into the subsurface of wastes and waste-generated fluids that are not in chemical equilibrium with the rock mass; and (3) ther-

mal disturbances of some sort, very large if hot wastes are introduced; this stress compounds the mechanical and chemical perturbations.

A major engineering task in any repository will be to prevent water from entering the workings through fractures caused by the mining process. All excavations produce a disturbance in the in situ [*sic*] stress field. This disturbance can produce fracturing in the vicinity of the underground working. Most estimates suggest that this mechanical disturbance extends for distances that are about the same as the size of the underground opening (Cook, 1977). The mining disturbance can only increase the permeability of the rock in the vicinity of the repository. Moreover, current estimates (Union Carbide Corp., Nuclear Div., Office of Waste Isolation, 1977) suggest that the backfilling process will fill the underground workings to a density of perhaps 80 percent of what it was before mining. Plastic deformation in shale and salt may, however, ultimately return these rocks to approximately their initial densities. In more brittle rocks, permeability may continue to increase even after backfilling of the repository as stresses are relieved. Shafts to the workings and exploratory holes in the vicinity of the workings will, of course, be carefully plugged but will still provide potential conduits for the entry and exit of water during substantial time periods.

Chemical effects brought on by the introduction of heat from the waste are discussed below. Chemical reactions that may take place at low temperatures are related to the incursion of fluids into the repository volume. These fluids will react with the waste components during long timespans, either dissolving them or producing a new waste form having changed solubility. For repositories in bedded or domed salt, the fluids at low temperatures will be saturated brines. The effects of these brines on the containment properties of salt are being studied at several laboratories. Interstitial brine is known

to reduce the mechanical strength of salt. Although scientists usually assume that water will never enter the workings of a repository in salt in amounts of more than 1 percent of the mass of solid salt and waste, the potentially serious consequences of greater amounts of water need to be explored. In addition to possibly entering through shafts and boreholes, water may enter a salt repository from brine pockets such as those that were found (unexpectedly) in one salt deposit (Boffey, 1975). The consequences of appreciable weakening of salt could be serious. One consequence could be an accelerated collapse of workings, which might facilitate sealing of a closed repository but would, at the same time, severely jeopardize retrievability and integrity in an active repository that was accidentally flooded. Another possibility is that the canisters or fuel assemblies could be moved in a direction determined by density contrasts and unrelieved stresses near them.

The presence of brine in a salt repository adjacent to waste canisters or fuel assemblies would create additional problems concerning the ultimate fate of the hazardous nuclides. The protective metal canisters and sleeves will certainly degrade quickly in the strong brine environment, and leaching of the wastes will be enhanced. Ultimate containment will therefore depend on the enclosing salt mass itself. Elements from the waste will be partitioned into the brines depending on such factors as complex formation, ion exchange, particle suspension in the dense brine, and colloid dispersion. The meager data available on this problem suggest that many elements will be partitioned into the liquid phase and that few elements will be partitioned into the solids. In other words, the capacity of salt to "fix" or adsorb the nuclides from the waste in insoluble form is apparently low. This is a widely recognized serious drawback of salt as the repository medium; the mechanical integrity of the salt medium thus becomes of extreme importance. A possible

way around this difficulty is to wrap the wastes in materials that do have a strong tendency to fix the nuclides from the wastes; research on possible materials is beginning.

The amount of heat introduced into a host rock by the waste depends on the form of the waste. Canisters of high-level waste may produce as much as 5 kW 10 years after reprocessing (ERDA, 1976); this output declines to one-tenth of this value within 100 years. Spent fuel assemblies have lower heat output, approximately 0.5 kW 10 years after removal from a reactor (Jenks, 1977), although the decay is less rapid.

Thermal energy introduced into the rocks surrounding the repository may cause complex mechanical and chemical changes. Increased temperatures in salt would further decrease mechanical strength of the salt-brine mixtures discussed above and would increase the creep rate of dry salt. Thermal expansion and later contraction will cause compressional and tensional stresses in confined media and may lead to widespread fracturing in brittle rocks. Preliminary calculations of thermal effects in brittle media have been carried out (for examples, see Ratigan, 1976). Usually such calculations use finite-element or finite-difference methods and deal with relatively close-in effects. A difficulty in such calculations for shale is lack of knowledge of the thermal properties of shale in three dimensions.

One of the more significant chemical changes caused by the introduction of thermal energy to a rock system will be the breakdown of hydrated minerals and consequent release of water. For example, mixed-layer montmorillonite-illite, a common constituent of shale, undergoes a phase transition involving increase in illite layers and the liberation of free water starting at temperatures as low as 100°C (Perry and Hower, 1972). At elevated temperatures in shale, this water will probably be in the form of steam. Oxygen, carbon dioxide, sulfur, and halogen gases may also be released. Interaction among preexisting minerals, volatile components, and waste will be

promoted by high temperatures. Experience from the Geological Survey's geothermal studies indicates that hot moving fluids may alter existing minerals and form new ones, thus causing significant changes in permeability. Some of these changes could reduce permeability and fluid flow (Summers and others, 1978). These mineralogical changes may be accompanied by volume changes and attended stress on the confining medium.

Thermal energy can also drastically modify hydrologic flow regimes by: (1) creating and driving convection cells; (2) inducing pressure gradients in fluids by thermal expansion, including the formation of systems containing both liquid and gaseous phases; (3) decreasing viscosity of fluids; (4) changing the bulk permeability; (5) changing the rock-stress field in a manner to strongly affect the fluid-flow field; and (6) changing solution chemical characteristics. Participants in a symposium on the movement of fluids in largely impermeable rocks (Union Carbide Corp., Nuclear Div., Office of Waste Isolation, 1977) concluded that no adequate model now exists to describe fluid flow, energy or chemical species transport, or source kinetics during the time interval of the thermal pulse, namely, the first several hundred years after burial.

Conservative limits may need to be placed initially on the thermal load to be borne by a radioactive-waste repository until many of the problems outlined above have been resolved. We are not saying that it is not feasible to store hot wastes in a deep geologic repository. We are saying, however, that given the current state of our knowledge, the uncertainties associated with hot wastes that interact chemically and mechanically with the rock and fluid system appear very high.

A general rule might be to restrain the permissive maximum temperature to a level lower than that which will cause a gas (steam) phase to appear. The gaseous phase is to be avoided, if possible, because, among other reasons, its lower viscosity and larger volume than those

of solid or liquid phases permit more rapid movement through porous media. The stress field and the presence of steam may interact to concentrate solution processes or chemical reactions in mechanically stressed regions near repositories; such interactions are still poorly evaluated, though they are potentially sources of breaches in containment.

Allowing the wastes to dissipate heat before burial also widens the spectrum of usable media. Montmorillonitic shales, for example, undergo a phase transition already mentioned involving reordering of mineral structure and release of free water at temperatures as low as 100°C. The fact that such mineralogic transitions yield large volumes of fluids is a possible deterrent for placement of hot wastes in such shale. Massive zeolitized ash-fall tuffs, which are common over large areas in the Basin and Range province of the United States and which locally are as much as hundreds of meters thick, are also attractive as potential media for waste disposal. They have most of the same desirable properties as the montmorillonitic shales; they are low in permeability and very high in sorptive capacity (Ramspott and Borg, 1977). Unfortunately, phase changes starting at about 150°-200°C cause the release of free water and may preclude use of zeolitic tuffs for the disposal of hot wastes. Crystalline rocks have few of the hydrous phases present in shales and tuffs; their thermomechanical response to hot waste is unknown, however.

THE GROUND-WATER SYSTEM

The acknowledged most likely process for moving radioactive waste from repository to biosphere is transport by ground water. Model predictions of the fate of the emplaced waste must therefore take into account factors that affect transport by ground water. These include: (1) convective transport by the flow, (2) dispersive and diffusive transport, (3) chemical interactions with the rocks along the flow path, and (4) rates at which the wastes come into solution.

In the simplest one-dimensional case in which ground water flows through a porous medium, the velocity of flow is given by Darcy's law, which states:

$$v = \frac{-k}{e}\,\frac{\delta h}{\delta l}$$

where v is the average velocity of the fluid, k is the permeability, e is the porosity, and $\delta h/\delta l$ is the gradient of the hydraulic head. The average distance moved by water during an interval of time is a crude measure of how far long-lived radionuclides might be transported, assuming that the velocity field is uniform both in time and space, and that, as a worst case, the radionuclides are not sorbed by the porous media traversed. If, for example, we wished to restrict transport to 1 km in 10^5 years, the flow velocity should be no more than about 3×10^{-8} cm/s. Further, assuming a head gradient of 1/100 (1 percent) and a medium having a porosity of 10 percent, we compute a permeability along the flow path on the order of 3×10^{-7} cm/s (about 0.3 millidarcies). This permeability is not particularly low for natural rock materials. Rocks that have "intergranular" permeabilities at least this low include "tight" sandstones, shaly siltstones, a variety of shales, and many crystalline rocks, including most granites. The current DOE program to establish waste repositories is directed toward salt, shale, and crystalline rock in part because these media have low permeabilities. As the porosities of such media decrease, or as the head gradient increases, the permeability must be lower in order to maintain the same velocity of water flow. Several other factors in ground-water transport act to speed up or slow down the flow of contaminants.

Contaminants disperse and diffuse at the front of an advancing wave of ground water bearing such contaminants and tend to spread out their concentrations. These effects cause some contaminants to arrive faster than

would be predicted by the average velocity of water movement (streamline convection) alone.

Adsorption and chemical reactions, including adsorption, ion exchange, and precipitation, retard or restrain the movement of some contaminants. Adsorption and ion exchange are strongly dependent on the chemical form of the contaminants, including their oxidation state and extent of complexing. Numerical measures of the sorptive properties of various chemical species vary through many orders of magnitude. They have yet to be determined for many of the actinide elements under repository conditions. However, the basic principles of these reactions are well known.

In order to construct a complete model of contaminant flow, the availability of the waste to percolating ground water must be known. This availability will depend in part on the form of the wastes. High-level wastes from reprocessing may be cast in a glass form that would have very low leachability (Marsily and others, 1977; ERDA, 1976); the leach rate of spent-fuel material appears to be comparable (Katayama, 1976). Even if the wastes have very low leachability, some contaminants will be released, and the rate of leaching may change significantly with time as the waste undergoes radioactive decay, interacts with the enclosing medium, or comes in contact with ground water of changing composition.

In summary, combinations of hydrologic factors can slow transport between the repository and the biosphere. Factors tending to lengthen the transport time include: (1) low permeability of the media, (2) high effective porosity of the media, (3) low gradient of hydraulic head, (4) high sorption capacity of the media, (5) long flow path, and (6) low rate of release of solutes by the wastes to the transporting fluids.

From the preceding general outline of factors influencing ground-water transport of radionuclides, preparing a

predictive model of contaminant transport might appear relatively simple. Unfortunately, several large gaps exist in knowledge of the details of natural transport systems.[2]

Media in which ground-water flow is largely through fractures are apt to be present in any flow system and pose problems in predicting radionuclide transport. The presence of fractures increases the velocity of flow under the same gradient. Fracture flow velocity may be a few orders of magnitude faster than intergranular velocity. In addition, the sorptive capacity of fractured media is likely to be lower than that of a porous medium because the fluid is in contact with much less of the medium for shorter times.

In theory, fluid flow through fractured media can be predicted in two ways:

1. The flow through a network of fractures can be analyzed. The geometry of the network of fractures must be known, and thus the orientation of fractures and the size of fracture apertures must be known. Although the geometry of the fracture system may be known in the vicinity of an underground working, it seems difficult, if not unfeasible to know this in sufficient detail at any distance from the few boreholes or workings likely to be permitted at or near a repository.

2. The fracture system can be analyzed stochastically. This analysis uses variables such as permeability and porosity that are analogous to those for a porous medium. Unfortunately, this method of analysis is relatively recent and, as yet, is untested on a field scale.

In addition to natural fractures, manmade boreholes in the vicinity of the repository as well as in the repository itself present problems. They must, even during hundreds of years, be considered as potential short-circuit pathways that could permit water flow from the repository horizon upward to shallow aquifers that may be utilized by man.

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[2] These uncertainties were the subject of a recent symposium (Union Carbide Corp., Nuclear Div., Office of Waste Isolation, 1977).

In addition to the problem of ground-water flow through fractures, a second major hydrologic problem involves measurements of fluid head and permeability in porous media of low permeability. These values are needed to characterize the hydrology around a repository, but meaningful in situ [*sic*] measurements of ground-water flow in low-permeability porous media have not been obtained routinely in the past. Although laboratory measurements of relevant variables are possible, experience in hydrology suggests that such measurements commonly vary by an order of magnitude or more from those obtained through in situ [*sic*] tests. The problem is compounded by the large number of variables that must be measured to describe the transport process through fractured porous media of low permeability.

The carbon-14 dating method provides a quasi-independent check on hydraulic computations of ground-water velocity, but only for waters that have been removed from the biosphere for less than 40,000 years, the practical limit of ^{14}C dating of ground water. In all likelihood, the waters in the vicinity of most potential repositories will be at least tens of thousand of years old. Radioactive disequilibrium studies using the systems $^{234}U/^{238}U$ and $^{230}Th/^{234}U$ offer some potential for dating ground water 10,000 to 1 million years old; these methods need considerable refinement before they can be routinely applied, however. Another potential technique for determining rates of ground-water flow in some rocks involves measuring the amount of dissolved helium in the water and comparing this measure to the amounts of uranium and thorium that yield helium through radioactive decay in the rock traversed (Marine, 1977).

In order to predict contaminant movement, the physical and chemical properties of the media that control transport must be known for a length of flow path sufficient to describe the movement for the requisite radionuclide containment time (Apps, 1977). Although measuring these

properties seems feasible, the manpower and observation time needed are not trival [*sic*]. We need, as a minimum, the permeability and porosity of the media and the hydraulic head gradients all in three dimensions. In addition, we need to know the sorptive characteristics of the media along all paths, and we need to estimate the variable rates at which the solidified wastes will enter the transporting fluids. Needed, in particular, is information on the distribution and extent of major heterogeneities. The need for such data severely taxes both the available data base and the technology for generating it. Most of the requisite data are presently unavailable; most of the available data have such large error limits that their usefulness in predictive models is limited (Philip, 1975). Indeed, in a recent review of ground-water models in general, Bugliarello and Gunther (1974, p. 136) stated that "the complete description of the quality and quantity aspects of groundwater flow under complex * * * conditions * * * is still in the future." Some basic problems of geologic models in general are discussed below.

CONTAINMENT TIME FRAMES AND GEOLOGIC PREDICTION

The objective of geologic disposal of radioactive wastes in the ground is to preclude their reaching the surface or near-surface hydrosphere, and thereby the biosphere, until they have decayed to a point at which their concentrations no longer constitute a health hazard.[3] Common geologic processes capable of transporting wastes to the surface or near surface after deep burial include ground-water movement, tectonism, diapirism, erosion, and volcanism. Equally important, tectonism, erosion, seismicity, glaciation, and climatic change may alter the initial conditions

[3] We recognize that definition of what might constitute a health hazard upon release of selected radionuclides to the hydrosphere involves consideration of many biologic and surface-hydrologic processes capable of reconcentrating the wastes. In this report, we are concerned exclusively with pathways in the lithosphere.

of ground-water flow described in the preceding section. Fracture permeability, hydraulic gradients, and flow-path length are all subject to change, and predictive models must take into account the probabilities of such changes (Burkholder and others, 1977).

How Long Is Necessary?

How long must the wastes be sequestered and the individual and interactive effects of the processes discussed above be predicted? Different radionuclides require different containment periods ranging from several hundred to several million years. Six hundred years is the period commonly cited as mandatory for containment of ^{90}Sr and ^{137}Cs, which are expected to constitute 99 percent of the projected curie (Ci) accumulation in reprocessed waste by the year 2020 (Gera and Jacobs, 1972, table 2.5). These fission-product nuclides have half-lives of 29 and 30 years, respectively. Every 10 half-lives of a nuclide correspond roughly to a 1,000-fold reduction in radioactivity; hence, after 600 years, or roughly 20 half-lives, the activity of these nuclides is reduced to $10^{-3} \times 10^{-3}$ or 10^{-6} (one millionth) of its initial value.

Other longer lived fission products will also be present in the waste, depending in part on its form. Spent fuel assemblies, for example, contain significant quantities of ^{129}I that has a very long half-life of 1.6×10^7 years and that poses a potential hazard at least this long.

The toxicity during periods as long as 10^7 years computed for radium and selected actinide elements and actinide daughters in high-level waste from reprocessing are shown in figure 1; the toxicity computation is based on the hazard from ingestion. Such a measure of toxicity takes no account of pathways to the biosphere and to man (Pigford and Choi, 1976) but does help to pose the question of how long a time must be considered in geologic predictions to assure safe containment of waste. The critical feature of figure 1 is the very slow dropoff in total po-

tential toxicity during the time indicated. As Gera (1975, p. 14) stated, "The variation in potential hazard from 100,000 to 10 million years is so limited and slow that it is virtually impossible to make a rational case for any specific length of required containment falling within that time interval. Either a containment failure can be considered acceptable after a period on the order of 100,000 years, or containment must be assured for periods of time exceeding at least 5 million years." Gera (1975, p. 14) considered that assuring containment for longer than 5 million years is "clearly impracticable since totally reliable geologic predictions of the detail required over such long time frames are beyond present capability."

Figure 1 also calls attention to the hazard from uranium mill tailings, which, although more than an order of magnitude more toxic than high-level waste, have customarily been treated in much more cursory fashion. Whether the hazards from high-level waste and uranium ore bodies and their derivative tailings are comparable is not clear. The high-level wastes are in highly concentrated forms. This means that a breach of a repository and a direct short circuit to the biosphere could have serious consequences. On the other hand, the relatively low volumes of high-level waste should help to insure that it can be more easily handled and placed in a more secure geologic environment than the more voluminous and dispersed ore and mill tailings (Pigford and Choi, 1976).

Geologic Prediction

Although the hazards from geologically isolated radioactive wastes during long periods of time are difficult to specify exactly, it is pertinent to ask, "How credible are geologic predictions ranging from 1,000 to 10 million years into the future?"

We have not had, of course, any working experience with geologic containment for such long periods; thus,

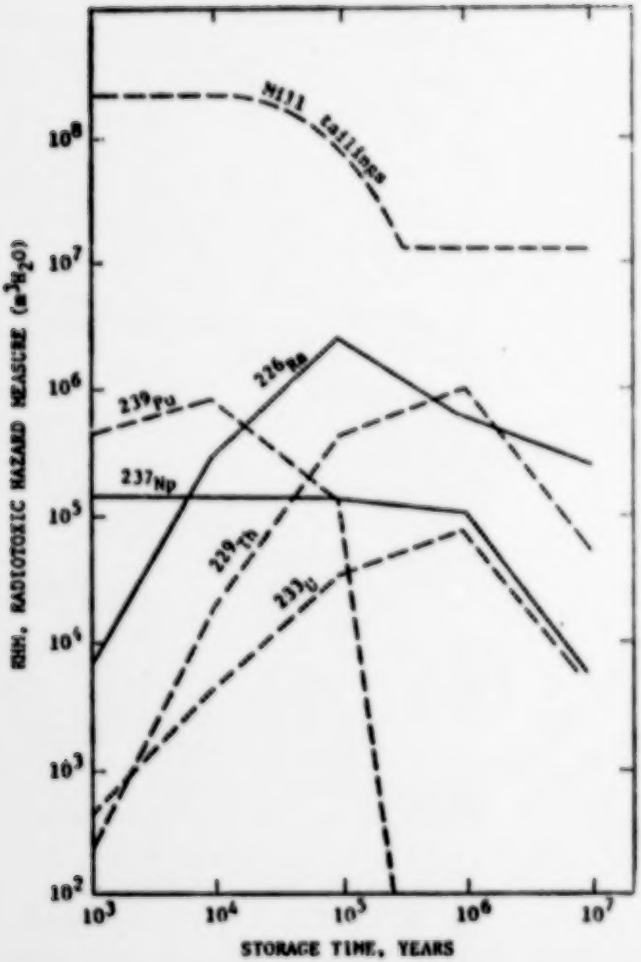

FIGURE 1.—Ingestion hazard of selected radionuclides in high-level waste during 10 million years. The radiotoxic hazard measure is obtained by dividing the number of curies present for a given nuclide by the number of curies produced by the maximum permissible concentration of that nuclide in a cubic meter of drinking water. Data are normalized for 1 metric ton of light-water reactor fuel. The nuclide curves are plotted from data in table 2 of Hamstra (1975); the curve for uranium mill tailings was derived from figure 2 of Hamstra (1975) and figure 7 of Pigford and Choi (1976).

predictions must be based on conceptual models of what will happen to the waste after emplacement. Such models exist, and their complexity and sophistication have been increasing steadily in recent years (for example, see Logan and Berbano, 1977; Burkholder and others, 1977; Tierney, 1977). In theory, the models provide a compendium of all possible events and processes likely to influence release of radioactivity from a repository to the biosphere and eventually to man. Connected with each event or process is an estimate of its future probability or rate. Potential interactions among the events and processes are also identified, and estimated functional relationships are incorporated into the models. The starting point for the models is a set of initial conditions, including emplaced radioactivity, rock geometry, and rock properties around the repository and along potential flow paths. The end point for the models is a set of risks usually expressed in radiation exposures to humans for a series of times after final disposal.

Application of these models to policy making in the field of radioactive-waste management requires that their limitations be clearly understood. Models of natural systems that have come into use in recent years fall into four categories (Holcomb Research Inst., 1976): (1) simple and predictable, such as agricultural crop patterns; (2) complex and predictable, such as river hydrology or short-term and weather patterns; (3) simple and unpredictable such as ecosystem response to natural disasters; and (4) highly complex and unpredictable, such as interrelations among the species of an ecosystem or, we believe, the fate of radioactive wastes in geologic repositories. The unpredictability of radioactive-waste models stems from the lack of a method for determining the future rates of many events and processes, such as tectonism, and from the current lack of adequate data needed to allow the model to function from start to finish—for example, the data needed to characterize ground-water-flow systems.

Past geologic events such as faulting, seismicity, or climate change probably have not been random, but deterministic explanations for their frequency, place of occurrence, magnitude, and rate of change are difficult to establish. Regardless of whether deterministic or probabilistic models are favored to explain particular past geologic events, use of the geologic record to predict future events is a formidable task. Certainly, an assumption of the constancy of rates of geologic processes, namely substantive uniformitarianism,[4] is open to question. The past rates of occurrence of geologic events and process have varied widely over time and there appears to be no clear philosophical basis for determining rates for these events or processes in the future. Geology is basically a retrodictive rather than a predictive science (Kitts, 1976). A related problem is that the observational record of the past, on which estimates of the rates of occurrence of geologic events are made, is invariably incomplete (Ager, 1973). The seismic record for most of the United States, for example, extends back only about 200 years. For some parts of the stable interior, clusters of relatively few low-level events suggest that larger events have a finite probability of occurrence, but estimates of this probability must be assigned relatively high errors (S. T. Algermissen, oral commun., 1977). These considerations are not meant to suggest that the geologic record of the past can be ignored in siting radioactive-waste repositories, but only that estimates of probabilities of future events be recognized for what they are—estimates only. Although many of the current gaps in needed data and theory will be filled eventually, Burkholder and others (1977) noted that many processes probably can never be modeled precisely. For example, the exact form

[4] Substantive uniformitarianism contrasts with methodologic uniformitarianism that asserts merely the spatial and temporal invariance of the natural laws such as gravity. These concepts were discussed extensively by Gould (1965a, b), Hubbert (1967), Albritton (1967), Hooykaas (1963), and Simpson (1963, 1970).

the waste will have thousands of years after disposal probably cannot be determined with certainty from either laboratory experiments or theory.

Of particular concern in assessing the uncertainty of geologic prediction is the effect of complex interactions among events and processes whose individual effects may be simple. Natural events such as earthquakes may affect a backfilled repository containing fluids very differently from the way in which they affect undisturbed rock; seismicity may itself be induced by fluid pressures. Potential interactions such as these must be analyzed in any systems analysis approach to waste isolation. However, unanticipated interactions have taken place in many engineering efforts whose components were presumably well characterized; the Apollo 13 near-tragic explosion is a conspicuous example (Cooper, 1973). Simpson (1963, 1970), Scriven (1959), and Mayr (1961) argued that long-term prediction in the biological and earth sciences is unreliable and impossible to perform with high confidence limits because of the great complexity of possible interactions among processes, both identified and unidentified.

Although validating a waste-management model for the timespans of concern will never be possible, we can ask the pragmatic question, "How good has the track record been in predicting the geologic response to man's disturbances for a shorter time, say 100 years?" Briefly, predictions in "routine" engineering geologic endeavors ranging from soil consolidation to tunnel geology have varied from good, in particularly favorable circumstances, to poor in some others where data seemed adequate and reliable (Lambe, 1973; Dowding and Miller, 1975). Two major difficulties revealed in studies of incorrect predictions have been the geologic definition of the medium and the choice of boundary conditions, rather than the mathematical modeling. The record may be even worse than it appears, for as Lambe (1973) pointed out, many published and apparently successful predictions were made

after the fact; he cautioned against overreliance on such predictions as opposed to those documented before the events took place. The interested reader is referred to the highly pertinent papers by Lambe (1973), Dowding and Miller (1975), Rowe (1975), and Meigh (1976) for details.

In summary, predictive models are an essential step in the selection and implementation of a radioactive-waste repository and a radioactive-waste management system. They are invaluable tools for analyzing the problem and for identifying factors that are likely to have the greatest effect on radionuclide migration. However, some components of the models are inherently unpredictable at present and are likely to change at different times. In no sense, therefore, will these models give a single answer to the question of the fate of radioactive waste in geologic repositories; rather they will provide a spectrum of alternative outcomes, each based on a set of uncertain assumptions about the future. Decision makers outside the earth sciences will have to evaluate these uncertain predictions in the light of pressing social and economic concerns.

RESEARCH NEEDS AND CONCLUDING STATEMENT

This Circular has dealt largely with the difficulties and uncertainties connected with the geologic disposal of high-level radioactive waste because, from our viewpoint, these are significant potential stumbling blocks that need critical attention. In emphasizing these problems, we do not intend to slight the extensive effort currently going forward to find safe repositories. Significant progress is being made. We offer the following suggestions for research efforts and emphasis in the hope that they will prove constructive.

First, the many questions concerning the behavior of rock salt must be resolved—questions centering on its high solubility. If relatively small amounts of brine can

cause substantial decrease of mechanical strength and possible movement of waste during a relatively short time, special efforts will surely be necessary to insure retrievability from a salt repository for periods as short as 10-25 years. The question of whether the workings of a mine in salt can be predicted to stay dry will have to be faced.

Second, systematic examination of media other than salt should continue. Some of the advantages of shale, crystalline rocks, and zeolitic tuff were mentioned earlier. The suggestion of Winograd (1974) that waste be placed at relatively shallow depths (30 to several hundred meters) in the thick (as thick as 600 m) unsaturated zones of the arid Western United States deserves consideration. The uncertainties connected with all these media are greatly reduced if the media are used, at least initially, only for relatively cool waste (surface temperatures $<100°C$).

Third, the complex task of characterizing ground-water transport systems around potential repositories should continue, and this task should be recognized as costly and time consuming. Empirical data on flow through fractured media and on the detailed chemistry of sorption-desorption phenomena for the actinide elements need to be collected and used on conceptual models.

Fourth, more tools to evaluate potential repositories should be aggressively developed. Although it may seem unduly cautious to call for still more technology and more types of data, we see the need to devise methods of dating old (greater than 40,000 years) ground waters and of exploring the volume of rocks around the repository as amply justified by the seriousness of an inadvertent breech [*sic*] of a repository.

Fifth, more research emphasis is needed on the relatively short and long term effects of the repository structure and the waste on the environment around the repository. Such research should address the question of the extent to which the repository itself can localize escape of radionuclides to the environment.

A concluding statement concerns the uncertainties involved in geologic prediction for long timespans, discussed earlier. These uncertainties need to be faced candidly in public discussions of radioactive-waste disposal. Earth scientists can indicate which sites have been relatively stable in the geologic past, but they cannot guarantee future stability. Construction of a repository and emplacement of waste will initiate complex processes that cannot, at present, be predicted with certainty. The inability to predict can be offset in part by adoption of a multiple-barrier or "defense-in-depth" philosophy for radionuclide containment. Such a philosophy provides a succession of independent barriers to nuclide migration. The waste form, the host rock, and the ground-water flow path all provide potential barriers. Continuing research is needed to measure the efficacy of these barriers and to obtain a better understanding of the processes involved.

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United States Environmental Protection Agency | Office of Radiation Programs Washington DC 20460 | EPA/520/4-78-004

Radiation

STATE OF GEOLOGICAL KNOWLEDGE REGARDING POTENTIAL TRANSPORT OF HIGH-LEVEL RADIOACTIVE WASTE FROM DEEP CONTINENTAL REPOSITORIES

Report of An Ad Hoc Panel
of Earth Scientists

[* This document was included by reference and relied on by, *inter alia*, NRDC in its presentation docketed on November 17, 1978. *See* Certified Index to the Administrative Record in U.S. Court of Appeals Docket Nos. 79-2110 and 79-2131, Vol. 32, Doc. No. 15 (reproduced *supra* p. 109). *See also supra* p. 219 n.23. The portions included from the Report consist of Part IV (Candidate Lithologies), Part V (Solution Transport through Rocks), Part VI (Radionuclide Transport Forecasting), Part VII (Geologic and Other Accidental Hazards), Part VIII (Monitoring the Repository) and Part IX (Conclusions). The references have been omitted in printing.]

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PART IV: CANDIDATE LITHOLOGIES

Several different rock types have been discussed as possible host lithologies for the HLW repositories. Important candidates are: salt, shale, granitic clan rocks, and basalt. Because of the undemonstrated security of the assemblages of materials in and immediately around the canisters, the containment by the rock that is the host of the repository becomes of paramount importance. This is probably the last stage of containment of the HLW prior to entry into circulating ground waters and contact with the biosphere.

We do not attempt to review the properties of the different lithologies. Rather, we focus on the physical and chemical properties that bear directly on the question of HLW transport.

The first category discussed is salt. This occurs in two ways in nature, as bedded salt deposits in a sedimentary sequence, and as salt domes. Because their characteristics are quite different, they are treated in different subsections.

IV.1 SALT BEDS

Bedded salt deposits are commonly believed by those unfamiliar with them to be massive, thick, pure beds of the mineral halite (NaCl), and this is the usual basis for model studies. Though there are a few local places where such beds can be found, most salt beds are more typically somewhat thin-bedded, may alternate with other evaporite deposits such as anhydrite ($CaSO_4$) or other salts (of the KCl-$MgCl_2$ groups), and are frequently separated by thin beds of shale. Salt is commonly interbedded with limestones or dolomites or may interfinger with them laterally. Salt beds may also grade laterally into sandstones.

On a microscopic scale, it can be seen that many halite crystals contain liquid (brine) or solid (anhydrite) in-

clusions. A recent report by Roedder and Belkin estimates the volume of these inclusions to be less than 1% but "an additional possibly even greater volume % fluid is present *in situ*, filling intergranular pores." [3]

There is abundant evidence for post-depositional recrystallization, differential solution, redeposition in cross-cutting veins, and mass flowage in evaporite deposits. The textures produced in salt beds by these processes increase the heterogeneity produced by depositional processes. There is also ample evidence of solution channels being established along veins and lithologic breaks.

Because salt is so soluble it rarely crops out at the surface; thus its stratigraphy and detailed lithology are mainly known from drill hole records. Though individual distinctive laminae have been traced for long distances through the study of drill cores, most of our information comes from geophysical logs of drill holes or shallow seismic profiles. Neither is adequate to show the amount and number of thin shale, anhydrite, or limestone breaks in salt beds. For this reason, site testing needs a carefully designed drilling program that includes provision for continuous coring that would detect all lithologic breaks. No geologist can predict the presence of a truly homogeneous bed of salt 30 m thick without such a drilling campaign plus detailed, including microscopic, study of the core samples to determine their brine and solid inclusion content.

Realistic estimates of water and brine content of salt beds are critical to proper estimation of the fate of canisters sealed in a salt repository, for, as indicated earlier, such hot briny solutions may effectively corrode the metal canister, leach the HLW matrix, and transport dissolved radionuclides. Water content is also important in affecting the creep rate of salt.

Recent experiments in the Experimental Geochemistry and Mineralogy Branch of USGS by D. B. Stewart and

others[4] have shown that at 200°C, water in a rock salt including potassium and magnesium components can contain approximately 70 wt % of dissolved salts. This implies that as little as 1 wt % H_2O in a salt bed may yield fluid that is 3 wt % because of the high concentration of the solution. The dissolving power of such brines should not be underestimated. We know from many hydrothermal experiments that because of changes in hydrolysis constants and the association of ion pair complexes, highly saline solutions at elevated temperatures are highly acidic—the pH can be as low as 2.

It should be noted that the pressure-temperature conditions near the canister may result in the brine becoming two phases (liquid and vapor), which could retard brine access to the canisters. The activity (in a chemical sense) of the brine components would still be the same in the two phases, however, and the liquids would still act as buffers to maintain the corrosive attack on the canisters.

These solutions would strongly attack any metal and effectively leach glass. There is also the possibility that permeation of these solutions along glass grain boundaries and incipient fractures would speed up devitrification, which would then feed back positively to enhance leaching.

Because of the high density of the canister, it might sink in any salt bed that contained the above quantities of saline water solutions, being corroded and leached as it moved downward. Many beds of salt overlie permeable limestone formations and the canisters might end up there, in the path of ground water movement. Any lithologic breaks in the salt might impede that movement depending on the thickness and the rock strength. But solution movement may also be enhanced along those very breaks.

We emphasize the importance of knowing the water content of salt beds proposed for repositories, particularly

with the background and the experience at Lyons, Kansas, where considerable volumes of water migrated in an unpredicted manner. That problem arose as a consequence of dissolution of salt by ground water seeping into the repository. Seepage was along an abandoned drill hole that, like most, had not been cased and plugged. This puts a premium on picking a site where precise locations of all abandoned drill holes or old underground workings are known.

Though remote sensing techniques seem likely to be able to spot some surface manifestations of these underground penetrations to supplement state and company records, it remains to be proven by ordinary double-blind experiments that such detection is highly accurate. In this connection it is necessary to prove not only that holes identified from aerial photographs are in fact there, but also that all holes actually have been identified from the photograph—no mean task. If this assurance cannot be made, then modellers of repository behavior will need to take into account the probability of leakage of water into salt through such old holes.

Any abandoned drill holes discovered may disqualify a site if they cannot be properly plugged and sealed. If the well has penetrated the salt there may be a cavernous dissolved region around the hole. In addition, most such wells will show extensive caving of weak rocks in the section, which might provide an efficient vertical transfer path among various aquifers. Since metal casing cannot be guaranteed against corrosion over the time scales we have to consider, some impermeable and chemically inert cement to grout and plug the hole must be developed. This indeed may be an important requirement for any drill holes designed to explore a site for a future repository.

IV.2 SALT DOMES

Of all the geologic media suggested for the underground isolation of HLW from the biosphere, the rock salt in the dry domes of the Gulf Coastal Plain seems mechanically best for disposal (permanent isolation by backfilling and sealing) but probably not for long-term storage and ready retrievability. Room-and-pillar mining in salt is cheap relative to that in hard rock.

Given the time frame of a million years, one cannot claim that the probability of any geologic event is absolutely zero. However, the risks of catastrophic events like destructive earthquakes and volcanism, or of sudden, unpredictable changes in the secular rate of erosion, or of continental glaciation are evidently extremely small in the coastal regions of Texas and Louisiana, certainly as unlikely as they would be anywhere in North America.

Once a critical thickness of overburden had been achieved, Gulf Coast domes grew more or less concurrently with the deposition and loading of the sediments above them. Since the rock over onshore domes is now being eroded, further growth ("diapirism") should not be expected. There is no obvious reason why the coastal plain should not remain tectonically stable for at least another million years.

Below the superjacent cap rock, the lithology is remarkably uniform. Although bedding may have been contorted (it is not always so), the rock is typically free of open fractures. Although its lateral extent is limited, the salt is several kilometers thick, and it should be possible to identify a repository site at least 1000 m from the closest water-bearing strata. Some (though not all) salt domes appear to be remarkably dry and to have been so for some millions of years. Professor Robert R. Unterberger of Texas A&M University has been probing domes with 40-cm radar. In a dry salt mass like that of Grand Saline in northeast Texas, he is able to map reflections at

the boundaries with surrounding water-bearing strata, as much as 2 km distant from the transmitting antenna. He could not do so if the average water content exceeded on the order of 0.1%. (In the "wet" Weeks Island dome, on the contrary, attenuation of the signal is so high that no reflections are recorded, and he turns to sonar.) In a dry dome no lateral migration of ground water appears to have occurred over several millions of years. It is hard to imagine how any ground water could reach the repository and, hence, how any radioactive elements could reach the biosphere.

In a dry dome, the bulk density of the encapsulated HLW would presumably exceed that of the salt, so that containers would tend to migrate downward, all to the good, even if the high-temperature viscosity of the salt were low enough to permit significant movements over the relevant span of time. Thus disposal in salt domes is likely to be permanent.

We do not know whether the sinking will tend to "focus" the canisters, although this effect should be amenable to computation. By focusing we mean that the originally horizontal array will have not only a temperature gradient that decreases away from each canister site, but also a higher-than-expected local temperature at the center of the condensed array. As the canisters sink in the salt, will they be "refracted" inward toward each other? If they are, the central temperature would rise, leading to still faster sinking and focusing until very high temperatures indeed might be reached. This possibility should be studied. There is also an important corollary: additional production of HLW by sub-critical or even, conceivably, critical activity with the U, TRU, and water. We do not suggest that this will happen, but rather that the question be properly addressed. Enough is now known to permit a computational assessment.

Salt is a valuable mineral resource, but worldwide reserves are virtually limitless, so there is no logical reason

why a single dome should not be perpetually withdrawn and dedicated to HLW disposal. The possibility of human intrusion at a far future time cannot, however, be discounted.

IV.3 SHALES

Just as most salt beds are not pure and monolithic, shales are rarely homogeneous and uniform. A typical shale is a rock that is more or less silty and contains occasional interbeds or laminae of permeable siltstone or sandstone. Other shales may be interbedded with limestone or dolomite or grade into a calcareous shale and then into a shaly limestone.

To varying degrees shales may be thinly bedded or show fissility, the ability to break into thin sheets. They may also be cut by systems of joints and fractures, and, where the shale is traced into areas where the rocks are metamorphic, may show incipient fracture cleavage. It is just now becoming known that fracture cleavage in many shales is related to original conditions of sedimentation and early diagenesis that make it susceptible to breaking along certain zones. In general, the older and more physically and mineralogically altered the original mud becomes, the more brittle the resulting shale becomes.

Since approximately 70% of the sedimentary rocks of the earth are shales, it is not surprising to find a great many thick shale sections. Yet it is extraordinarily difficult to find one that is uninterrupted by interbeds of other, generally more permeable, lithologies. As in the case for salt beds, it is difficult if not impossible to get an accurate detailed log of a vertical section of most shales from outcrops because of their rapid weathering in most climates and topographies. At the same time, geophysical methods are inadequate to pick up fine interbeds and interlaminations. As thin as these may be, frequently on the order of a few millimeters in thickness,

there is good geological evidence that there has been sufficient water flow through these laminae to alter the clay mineralogy in the sandstone whereas the more impermeable shale is unaltered. Hence a requirement for a shale repository must be the acquisition and careful study of drill cores.

Shales are particularly susceptible to mineralogical alteration that promotes physical change if they come in contact with solutions of a different kind than they were naturally bathed in at depth. Shales are complex mixtures of quartz, feldspar, several varieties of clay minerals, zeolites, carbonates, sulfides and oxides. Any significant chemical reactions of these minerals are likely to weaken the physical structure and promote cracking and disintegration at the relatively low confining pressures of a repository. All of these reactions are promoted by increase in temperature.

Before any detailed plans for a shale repository can be drawn, the stratigraphic and mineralogical-geochemical work has to be done. The detailed stratigraphy and petrography we know how to do, but the study of how altered mineralogy affects physical structure is in its infancy. Long-term heating to 300-500° C is likely to induce mineralogical changes including dehydration of smectites. This dehydration could liberate significant quantities of free water and induce textural changes that might be reflected in fracture patterns, which in turn affect the fluid permeability of the formation. We cannot as yet predict such behavior of a specific complex mineral assemblage from general rules.

The USGS has done a fair amount of work on the merits of the Pierre shale of the Dakotas as a possible repository. The stratigraphic and mineralogical-chemical knowledge of the Pierre shale is possibly greater than that of any other shale in the world. We know that there are thick shale sections in it and that it has a generally stable

mineralogy. On the other hand, as much as we know, we still are unable to predict with any high probability what the fluid permeability is of such a section after long-term heating by buried HLW. And we are not able at this time to define how rare and how thin occasional interbedded silt laminae would have to be to prevent significant fluid migration in or out of the formation. At this time we could not rule out extensive fluid migration via fracture permeability following a 10-20-year period of moderate heating.

IV.4 GRANITE

Because they are widespread, underlie large regions of the mountain belts and shield areas of North America, are relatively homogeneous, have high crushing strengths (up to a few kilobars at low confining stress), low porosities and, therefore, low pore-water contents (0.01 to 0.03) and low permeabilities (10^{-7} to 10^{-17} cm^2), granitic rocks have good potential for development as high-level waste repositories. Large granite plutons range in thickness from 2 km to 15 km and, unlike sedimentary rocks, are not likely to have acquifers at depth. Retrieval of HLW canisters would be easier in granite than in most other rocks. However, granites are brittle, and we currently know neither their behavior under thermal stress nor their sorptive properties.

Many of the important physical properties of granite are site-specific, such as joint density and state of stress. Other site-specific features such as hydrothermal alteration zones, dikes, quartz veins, the irregular three-dimensional geometry of the granite body itself, and faults will all contribute, along with the joint pattern, to the hydrologic regime. It is the Panel's opinion, and apparently that of several foreign countries as well, that a sizable body of granite underlying a hydrologic basin of appropriate dimensions may prove, in the long run, to be an excellent underground repository. We know of no reasons, as yet, to rule it out. Research on granites should be pushed

vigorously, particularly because there may be either socio-political or geological reasons why burial in salt may be ruled out. In this case it appears that we have no fall-back position, and granite is an obvious alternative.

IV.5 BASALT

The presence of tens of thousands of square miles of up to a 5,000-ft-thick succession of plateau basalts in the northwestern United States, and their nearness to the Hanford, Washington and Idaho National Engineering Laboratories Waste Storage facilities have focused attention upon these rocks as potential HLW repositories.

Fresh massive basalt will have crushing strengths as high or higher than those of granite, and porosities, permeabilities, and linear thermal expansion coefficients that may be as low or lower. The coefficient of thermal conductivity for basalt and granite lies in the same range (5×10^{-3} to 8×10^{-3} cal/[cm][sec^2][°C]), but basalt is likely to be the higher of the two.

Although the laboratory measured physical properties of granite and basalt thus seem to be roughly equivalent, there are geological differences in their mode of occurrence that favor the former rock over the latter. The typical basalt flow of the Columbia and Snake River plateaus ranges from 10 m to 45 m in thickness, and is often separated from the overlying and underlying flows by an aquifer. Lower columnar and upper fan-type jointing of each individual flow is characteristic, and most lavas have a 5-m thick vesicular zone at the top, and a 1-m thick vesicular zone at the base of each flow. Thus it seems that, on the average, basalt should be far more porous and permeable than granite, and that it would also offer a higher risk of contaminating the ground water if used as an HLW repository. Advantages of some basalts would be their lateral continuity over hundreds of square miles, and the fact that some of the rocks are slightly altered and contain clays or zeolites, which may enhance the sorptive properties of the basalt. Unfortu-

nately, though there are some data on clay minerals and zeolites, there are no published data on the sorptive properties of well-described altered basalts.

The general feeling of the Panel is that because of geologic constraints, establishing a safe repository will be more difficult in basalt than it will be in granite. Finding a thick unfractured or unjointed basalt flow that can be opened up and resealed without the development of fractures that will communicate with an actual or potential interflow aquifer may be a requirement that is difficult to meet. Again, we know enough about the areal geology, stratigraphy, and general lithologic character of basalt, but would need means to determine the site-specific fracture permeability or bulk retentivity. At a minimum, a strong laboratory reconnaissance program would be needed in order to demonstrate the desirability of further consideration of basalt.

IV.6 OTHER ROCKS

It is appropriate at this point to comment briefly on other rock types that may have excellent potential as disposal hosts but have been largely ignored up to the present.

Analysis of thousands of water well records in places such as New England demonstrates that the flow of ground water in bedrock in these areas is entirely fracture-dependent, and that metamorphic rocks have very low porosities and negligible permeabilities. With increasing degree of metamorphism, such rocks become increasingly anhydrous and granular textured, approaching the igneous rocks in their general physical properties. High-grade metamorphic terrains are common in many mountain belts, as well as in areas such as the Minnesota Shield, the South Dakota Black Hills, and the Adirondacks. In the latter region they are associated with igneous rocks such as anorthosite, gabbro, syenite, and

charnockite, all of which are composed of anhydrous silicates and all of which are potentially usable depository hosts.

Dunite, a relatively uncommon igneous rock occurring in parts of the Appalachians and the Coast Ranges, has the unique property of being potentially self-healing. Access of water to an HLW canister in these rocks would result under the pressure and temperature conditions of burial, in the development of serpentine; the large volume increase accompanying this reaction would help to make the repository impermeable. It would need to be shown, however, that the process itself would not induce fracturing.

In a similar way, a proposal by Professor W. S. Fyfe that canisters be surrounded by a packing of MgO powder (which would hydrate to brucite—$Mg(OH)_2$—upon contact with water) is also worth considering as a safeguard against possible waste leakage.

PART V: SOLUTION TRANSPORT THROUGH ROCKS

The principal barrier to contamination of the biosphere by HLW is the time delay expected during the migration of the nuclides through the rock unit that contains the repository. This delay can be predicted from experimental data plus some assumptions regarding the particular setting, or from evidence of previously completed "experiments."

The first approach is based on data concerning three key factors: the actual rock permeability *in situ*, whether this be true permeability or flow through fractures; the flow rate; and the retardation, if any, of the dissolved nuclide relative to the flow of the water. Part VI will consider the first two factors. In this section, the third factor will be discussed and then the previously completed "experiments."

V.1 SORPTION OF RADIONUCLIDES ONTO ROCK MATERIALS

Critical to the operation of a secondary barrier to radionuclide migration is the ability of a rock through which fluids may slowly flow to adsorb or react with dissolved radionuclides. There is now an abundance of experimental data on the extent of adsorption of various fission products and transuranics by soil and rock materials. Unfortunately these experimental data are useful only in a general way and even then may be misleading.

The reasons are that for any such surface chemical process, the nature of the mineral surface must be specified precisely (mineralogical and chemical composition, surface area per unit of mass) and the experiment must be carried out under conditions similar to those expected underground. In addition, for experimental results to be meaningful a uniform methodology would have to be employed so that various materials and different elements could be compared on a sound common basis.

The experiments thus far performed have been on materials described variously as "desert soil", "tuff", "basalt", or "montmorillonite", to mention a few. None of these terms is a precise description that would allow anyone to infer what the chemical behavior of the material might be. "Montmorillonite" is a term used in many different ways by clay mineralogists and rarely to describe a specific mineral with a fixed composition and crystal structure. Specific standard clay minerals (American Petroleum Institute Standards) have been used, but only for the sake of comparison and not to give the impression that they are standard mineral types. Adequate description of any clay is made only by chemical analysis (either bulk or electron microprobe) coupled with crystal structure analysis by X-ray diffraction. Since the methods of sample preparation strongly influence surface area, these too must be specified. The ion-exchange capacity and selectivity of the clays used must also be determined.

The same comments apply to the use of rock terms such as "basalt" or "tuff", which are just field terms of gross lithology used for the convenience of the geologist mapping in the field and not in any sense the same as quotation of the precise chemical formula of a reagent.

Results of experiments conducted at 25°C and 1 atm. pressure are not a good guide to what might happen at 100°, 200°, or 300°C. We know of temperature-induced reversals in cation selectivity, exchange capacity, and sorption characteristics that are a result of surface configurational changes. In addition, all of these data are almost meaningless unless some realistic choice of solution is made. Formation waters of deeply buried rocks tend to be rich in dissolved solids, and this ionic strength can greatly alter sorptive properties of mineral surfaces. Cation adsorption is generally competitive, and radionuclides may be passed unsorbed if competing cations of formation waters have already been sorbed strongly onto surfaces.

What we can say with the information at hand is that we would expect certain classes of materials to be more retentive than others at room temperatures. Thus desert soils would have high retentivity and granites and salt low retentivity; with tuffs, basalts and shales lying between, we would expect notable cation exchangers, such as smectites and zeolites, to be highly retentive. But this is no quantitative basis for estimation of what will really occur in a specific formation at depth and at elevated temperatures. Before that can be done we need a carefully planned and executed program of testing by experimentation.

V.2 FIELD "EXPERIMENTS"

An alternative method to predict behavior of HLW transport through rocks is to examine natural settings where such transport might have occurred. Two such cases have been studied in some detail and can shed some

light on the process. These are the Oklo natural fission reactor discovered in Gabon, and the underground nuclear explosion test, Cambric, carried out in Nevada.

Approximately 1.8 billion years ago a uranium ore deposit experienced the appropriate conditions of U concentration, ^{235}U concentration, and H/U ratio for it to go critical and yield fissions and energy. This is known as the Oklo phenomenon. The four to six local zones where this occurred are thought to have produced 15,000 megawatt years (MW yr) of energy, over a period of approximately 0.5 to 1 million years. The site has been studied in order to determine the extent of loss of the various fission products and TRU's that were produced during and subsequent to the time fission was occurring.

The results indicate that the losses were largely dependent on the chemistry of the nuclides in question. Alkalies and alkaline earths were lost either completely or in very significant amounts. These would include the major fission product nuclides of concern, ^{90}Sr and ^{137}Cs [see Lancelot et al.[5]] On the other hand, the radioactive rare earth elements and the TRU's largely remained in or near the reactor zones.[6] A very precise material balance is not possible. It would not be surprising if 10% or 20% of the products in a given reactor zone had been lost.

The difficulty with the interpretation of the Oklo event is the lack of precise geological control. It is not clear to what depth these deposits were buried at the time of fission reaction. Some believe that the process was going on under fairly shallow burial, because the water that acted as a moderator had to be vaporized and this could only happen close to the surface. The sediments have been altered by heat and pressure to a state suggestive of burial to approximately 4,000 ft,[7] although there is a suggestion that the depth may be as much as 6 or 7 km. The mineral assemblages, their compositions, and their

fluid inclusions all suggest a variety of possible depths of burial so that no sure conclusions can be drawn. It is likely, however, that the depth was considerably more than the 1,500 ft envisioned for HLW burial.

The uncertainty concerning the depth of burial means that it is not possible to make a direct comparison of the Oklo phenomenon with an HLW disposal site. This is so both because of the dependence of the flow of fluids on depth (and the consequent variation in degree of openness of cracks) and because the distance that the nuclides would have traveled to reach the surface is not known.

Whatever the depth, however, there must be serious concern over the loss of the major fission products, ^{90}Sr and ^{137}Cs.

The second "experiment" is the Cambric nuclear test in Nevada and the subsequent water pumping tests conducted using drill holes at the site. The massive pumping tests conducted in the decade since the explosion have shown that the radioactivity that has entered the water is in very low concentrations. This is very encouraging.

Two factors that play a role here, however, make the test less relevant to HLW containment. The first is that much of the radioactivity is in a glass produced by the extreme heat of the explosion. This glass has had ten years to devitrify and be leached. Since little radioactivity is detected in the pumped water, it can be inferred that the nuclides are being retained. The problem is that the water is cold, and the pumping continues to bring cold water to the site. This test, therefore, is not using waters that are comparable to those anticipated in an HLW repository: hotter than 300°C and with high ionic strengths. As a result, the channels through which the water is flowing are behaving like pipes. Further, the very low concentrations of nuclides are partly due to the rapid flow rates, which serve to dilute the nuclides as they are released.

PART VI: RADIONUCLIDE TRANSPORT FORECASTING

The objective of the transport modeling considered in this analysis is to forecast the subsurface movement and evolution of radionuclides emanating from a radioactive waste repository under various hypothetical situations. Perhaps the most challenging aspect of this problem is the necessity to forecast over long time periods (250,000 years)[8] with uncertain information. In addition to the elements of uncertainty concerning the transport listed previously,[9, 10] the following also play a role:

- hydrologic characteristics of the site (primary versus secondary permeability and porosity, hydrodynamic dispersion),
- mathematical representation of subsurface transport, and
- solution of the resulting equations for realistic physical conditions.

Many of these uncertainties have been encountered in petroleum engineering and subsurface hydrology. In these instances, uncertainty is reduced primarily through the "calibration" process whereby the mathematical model and its input parameters are modified until a historical record (pressure history, concentration trends) is reproduced within a range of error deemed to be "acceptable." Obviously, the simulation of radioactive waste transport does not, in general, lend itself to a "calibration" form of uncertainty reduction. In summary, the problem is one of either minimizing the uncertainty outlined above such that a deterministic analysis (inclusive of sensitivity analysis) can be meaningful, or alternatively, incorporating this uncertainty directly into the analysis so that the decision-maker is cognizant of the degree of uncertainty inherent in the forecasts.

VI.1 STATE OF THE ART OF TRANSPORT MODELING

Two operational models are currently capable of simulating the movement of multiple radionuclides in the subsurface. These models have been developed for the Nuclear Regulatory Commission and the Energy Research and Development Administration (now Department of Energy) by Intera Environmental Consultants and Battelle Northwest Laboratories, respectively. (Note that we have not included the model employed by the American Physical Society Study Group on Nuclear Fuel Cycles and Waste Management because of the physical and mathematical simplifications inherent in their approach.) The salient features of the two models are summarized in Table 1. Examination of this information reveals that the Intera numerical model is the most physically realistic and flexible. The BNWL models, however, have the advantage of analytical simplicity and associated computational efficiency.

Burkholder et al.[11] have argued because of the nonreducible uncertainties inherent in some elements of the analysis of radionuclide transport, "that highly sophisticated transport models should be used with caution or perhaps not be used at all." They further state that such models "could create unwarranted illusions of certainty." The significance and importance of this point of view depends, of course, on the interpretation of the phrase "highly sophisticated."

In other branches of science and engineering, the evolutionary trend has been to minimize forecasting uncertainty through improved mathematical representation of the physical system and careful evaluation of associated physical parameters (see, for example, work in structures and mechanics, hydrology, meteorology, etc.). The use of a simpler model, however, is advantageous when numerous alternative scenarios must be examined, such as in a sensitivity analysis or an optimization algorithm. A com-

TABLE 1

CHARACTERISTICS OF TRANSPORT MODELS

Model Characteristic	Model INTERA	BNWL I	BNWL II
Dimensionality	3D Cartesian 2D Radial	1D Cartesian	2D Cartesian
Mathematical Formulation	Numerical Finite Difference	Analytical	Analytical-Numerical
Dispersion Representation	Variable, Function of Velocity, Tensor	Scalar, Constant	Scalar, Constant
Convection Representation	General Velocity Field	Constant Velocity Field	Spacially Varying Velocity Field
Species Transported	Multiple Radionuclides	Multiple Radionuclides	Multiple Radionuclides
Transporting Media	Saturated Porous Medium	Saturated Porous Medium	Saturated Porous Medium
Sorption	Linear	Linear	Linear
Source Dissolution	Variable	Constant	Constant
Chemical Form	Single	Single	Multiple*
Discrete Fracture Representation	None	None	None
Stochastic Capability	None	None	None
Geologic Strata	Non-Homogeneous	Homogeneous	Homogeneous
Temperature Dependence	Density, Viscosity	None	None
Solubility	Limited	?	?

*Under development

bination of both approaches, such as utilized by Intera in their report to EPA,[12] represents a cost-effective approach to investigating the problem of radionuclide transport.

VI.2 THE QUESTION OF UNCERTAINTY

There is little question that the models presented in Table 1 represent the state of the art of engineering capability in transport modeling. Certain degrees of sophistication could be included, such as a better representation of the fracture system, but these modifications are not likely to enhance the accuracy of the model forecasts materially, because of the uncertainties that will still remain.

It is more important to consider the possibility of quantifying the uncertainty in the model so that decision-makers are aware of the degree of uncertainty associated with the analysis. The simplest approach to quantifying uncertainty in simulation modeling is through a sensitivity analysis. Such an analysis was performed by Intera for EPA.[12]

In this approach, a range of parameter values is used in the predictions. These are selected so as to encompass the entire range of physically meaningful parameter values. Such an analysis provides an insight into the role of each model parameter on the calculated radionuclide distribution. To conduct such an analysis generally requires a tremendous amount of computational effort. To analyze two levels of the 12 parameters considered by Intera unambiguously would require 2^{12} independent simulations. Because this is prohibitive, even with use of analytical models, a subset of the general problem is normally considered and the results, of necessity, are indicative rather than definitive.

While a sensitivity analysis provides the decision-maker with a range of possible radionuclide distributions, it does

not give any insight into the probability of occurrence of any particular forecast. In simulations wherein large residual uncertainties in input are unavoidable, the uncertainty in the predicted radionuclide concentrations should be recognized and quantified. In other words, in an analysis of the radionuclide transport problem, the solution should appear as a confidence region (i.e., we are 95% certain the real concentration of ^{90}Sr lies between x and y, given the probability distributions of the input parameters). Thus, the reliability and importance of the forecast can be directly related to the reliability of the input parameters. To conduct such an analysis requires estimates of parameters and their uncertainty, and a suitable mathematical model.

Standard mathematical models such as presented in Table 1 can be modified for simulation under uncertainty. The procedure, known as Monte Carlo analysis, involves conducting a series of simulations in which parameter values are selected at random from their respective probability distributions. These values are used in simulation runs and the output variables, in this case radionuclide distributions, are assembled into probability distributions. From these distributions, confidence intervals can be computed. Such analyses, however, require excessive computational effort, particularly when several different parameter distributions are involved. Alternative schemes are available to circumvent these computational difficulties, but these cannot be considered at the time to be state-of-the-art engineering methodologies.

While uncertainty in the partial differential equations may be accounted for by use of new mathematical methodology, one must still consider the problem of estimating these uncertain parameters. Whether intentional or by default, these parameters will be subjective probability estimates. Tools are available and currently being developed to compute these estimates by use of objective and subjective information (see, for example, Bayesian meth-

ods). The credibility of forecasts made under condition of uncertainty will depend upon a reasonable representation of the probabilistic parameters. The impact of parameter uncertainty, that is the resultant uncertainty in the projections, is dependent on problem and boundary conditions. In example problems that have been considered,[13] situations were encountered in which the uncertainty increased, reached a maximum, and asymptotically decreased to zero as a function of time. Another case resulted in an exponential increase in uncertainty throughout the simulation period. Thus it is apparent that generalizations regarding the impact of parameter uncertainty on forecasts of radionuclide concentrations are not normally possible.

It should also be noted that uncertainties associated with parameters in the governing equations interact in such a manner that their individual contributions to the spread in the confidence interval of the projections cannot be discerned. Thus it is not possible, in general, to delineate unambiguously the importance of the uncertainty associated with, for example, the source term.

VI.3 CREDIBILITY OF THE ANALYSIS

At this point it is evident that uncertainty is the distinctive element of radionuclide transport analysis. While uncertainty is associated to some degree with forecasts emanating from all mathematical models of subsurface phenomena, this uncertainty is generally minimized through calibration with known historical data. Even where historical data are scarce, one generally reserves the option of measuring *in situ* hydrologic and transport parameters. Because the disposal site has not yet been selected, such measurements are not currently available. Moreover, even after site selection, the *in situ* measurement of parameters must be minimized to ensure the integrity of the site. Because of the apparent inability to decrease significantly the uncertainty associated with the

transport parameters, the only viable alternative is to incorporate as much of the uncertainty as possible directly into the analysis so that the decision-maker is aware of at least the minimal uncertainty inherent in the forecasts.

In evaluating the suitability of available radionuclide transport analyses as a basis for establishing radiation standards for high-level radioactive waste management, EPA should particularly consider the following:

- The existing simulations of radionuclide transport emanating from high-level waste are limited to a small number of hypothetical problems associated with selected waste-disposal scenarios. The results represent qualitatively the movement of the waste under these conditions. Although limited in number relative to the spectrum of hydrological settings possible for a repository, the problems selected represent a reasonable and relatively unbiased choice.
- The problems examined should be considered indicative rather than representative of situations to be encountered in the storage of radioactive waste.
- The relationship between the parameters and processes employed in the model and those to be encountered in a disposal site is very uncertain.
- The Intera model incorporates directly or indirectly (as in the case of fractures) those attributes of the prototype physical system most likely to play an important role in radionuclide transport from a repository. A possible exception is unsaturated transport.
- The credibility of the model and the associated analysis would be enhanced by a satisfactory simulation of radionuclide transport at the Nevada Test Site.

- Current models do not incorporate parameter or process uncertainty in their forecasts.
- The scenarios considered in the analyses are, in large part, arbitrary and may or may not encompass the hydrogeological systems to be encountered at a specific site.
- The general approach currently used by some consulting engineers for forecasting radionuclide transport, though strongly limited by the inherent uncertainty in the hydrogeologic, geochemical and chemical data input, nevertheless represents the best means currently available for establishing the movement of radionuclides if and when the proposed containment is breached and water comes in contact with the waste. We have considered the quality and applicability of the simulation methods but not their adequacy. The adequacy of the forecasts depends on the sensitivity of the decision-making process to the state of the art of transport modeling.

VI.4 PROPOSED RESEARCH

We have been asked to suggest techniques that would result in an improved capability for risk assessment regarding the HLW repository concept. In transport simulation, three areas appear to be prime candidates for further research:

- In order to incorporate the uncertainty associated with parameter identification, a program should be initiated that is directed toward the development of an analytical capability for forecasting under uncertainty. This would not involve great sums of money inasmuch as the primary goal is software development, which is not usually capital intensive. In the short term, it would appear reasonable and appropriate to employ existing tech-

niques for simulation under uncertainty in order to analyze one or more mathematically simple scenarios. This would at least provide a ball-park estimate of the uncertainty associated with the forecasts.

- Before the methodology developed in the preceding step can be utilized, estimates of parameter uncertainty must be available. These estimates can be obtained through an effective utilization of subjective and measured information. The analytical apparatus for this type of analysis is incompletely developed and should be considered a priority element of the research effort.

- Once uncertainty can be quantified and incorporated into transport forecasts, the next major objective is to minimize this uncertainty. This can be achieved primarily through additional field observation. Thus, a primary goal of a research program should be the *in situ* measurement of hydrological and geochemical parameters. Because of the nature of the repository, this methodology must be compatible with the maintenance of repository integrity. The liberal use of subjective information will minimize the cost and negative impact to the repository of data collection and, it would seem, provide a cost-effective program of parameter identification.

PART VII: GEOLOGIC AND OTHER ACCIDENTAL HAZARDS

Assuming that physical and hydrologic requirements for a safe HLW repository have been established, one must still consider whether all other factors that may disrupt the integrity of the site have been taken into consideration, and whether these factors are tractable to numerical risk analysis. As one report states, "At *some* point in the repository site and emplacement method selection

and safety assessment, whether willing or not, we *will* quantify in order to make decisions." [14] Without attempting to assess all non-geologic and geologic hazards, we shall comment briefly on some of them, primarily to illustrate the extreme numerical uncertainties attached to most.

VII.1 NON-GEOLOGIC ACCIDENTS

VII.1.1 *Intrusion by Man*

The development of an underground waste repository involves the breaching of what was probably initially an intact geologic container. After the repository has been backfilled, heating combined with the possible access of ground water will set up a convective hydrological system in which ionic transport rates will also be greatly accelerated. These features, as well as uncertainty about the long-term effectiveness of having sealed shafts in bedrock, are matters on which there are very few bases for judgment.

Intrusion of a repository at some future date in the search for mineral materials, including the uranium and TRU elements that were buried, or to satisfy archeological or other curiosities appears to us also to be a risk for which no trustworthy probability estimates may be applied for the time span over which the integrity of the repository is to be assured. Material demands shift with technology. The most successful civilizations last for only a few millenia at best, and even these are not without their disastrous interludes. Man's unpredictability far outstrips most of the imagined geologic hazards we can foresee, and we doubt that it is amenable to meaningful probability analysis.

VII.1.2 *Meteorites*

An astronomic risk that is generally cited is meteorite impact. The earth annually receives an infall of approxi-

mately 10^6 tons of cosmic dust, but meteorites large enough to produce craters the size of Meteor Crater in Arizona (1.2-km diameter), or larger, are estimated to have a frequency on the order of 1 per 20,000 years or less. The bedrock in a meteorite crater is pulverized to a depth of approximately one-tenth of the crater diameter, but the surrounding and underlying rock will be highly fractured. If one assumes conservatively that a repository at a depth of 0.5 to 1 km might be breached if it lay within a radius of 10 km from the point of meteorite impact, and also that the probability for impact is equally distributed over the earth's surface (5.1×10^8 km^2), the likelihood of meteorite damage is approximately 3.3×10^{-11}/yr, or 1/30,000 averaged over a million-year time span. Meteorites, therefore, should not be regarded as significant factors in evaluating repository safety. A more detailed treatment by Arthur D. Little, Inc.[15] yields similar results except for secondary effects such as stream diversion by impact. Given the need to make provision in the repository for major water table variation, this problem can also be given low significance.

VII.2 GEOLOGIC ACCIDENTS

The structure of the earth and energy sources that drive its physical processes are such that stochastic models are not widely applicable, unless one closely restricts the area of inquiry, and probably the time as well. We are aware that fault tree analysis is the numerical basis for risk assessment in the Rasmussen report on nuclear reactor safety.[16] However the question of assessing engineering failure by a surface facility over a 50-year time span is not the same problem as assuring geologic and hydrologic integrity at an underground site over a million-year time span, especially because there is information on reactor performance in the past.

VII.2.1 *Extrusive and Intrusive Magmas*

Aside from gradual subsidence of the Gulf Coast and the Mississippi Embayment commencing approximately 70 million years (m.y.) ago, and the isostatic depression and rebound of the northeastern and north-central part of the country in response to continental glaciation, the United States east of the Rocky Mountains has been geologically stable for approximately 100 m.y. In this vast region the youngest dated igneous rocks (dikes) have an age of approximately 70 m.y. For this entire area, then, the probability for a magmatic incursion into a waste repository during the next million years has to be taken as astronomically low, but numerically uncertain.

Along the entire Cascades chain, by contrast, the probability for a volcanic eruption may be on the order of 10^{-2}/yr. If there are an estimated 65,000 km^2 of potential volcanic terrane [*sic*] and a repository within a 10-km radius of a volcano might be adversely affected by an eruption, the average rate of risk per 300 km^2 is on the order of 10^{-4}/yr. However, it obviously makes a difference whether we designate one of these 300 km^2 areas as lying close to Lassen Peak, Mt. Baker, Mt. St. Helens or Mt. Rainier, or remote from them. Even for the remote areas, it is well to recollect that no one predicted or could have predicted the May, 1943 eruption of a new volcano at Paricutin, in the western Mexico volcanic belt.

For the area of intermediate magmatic risk lying between the Rocky Mountain Front and the Cascade-Coast Range Belt, there is no very good basis for speculating on numerical risk probabilities, nor is there any ready answer to why areas such as Sunset Crater, Arizona, and the Craters of the Moon, Idaho, have been active within the past few thousand years.

The situation with respect to magmatic hazard typifies what the Panel believes to be true of most other geologic

risks. Within different specified regions we may estimate a relative order of danger, but for very few areas can we have any confidence in orders-of-magnitude estimates of risk probabilities. Of all the world's volcanoes now under surveillance, Kilauea is one of the few whose short-term behavior is predictive. Even here, projections for a million years in the future are well beyond the current state of the art.

VII.2.2 *Earthquakes and Faults*

Even in regions of transform faulting where great earthquakes occur relatively frequently on the geologic time scale, like the active, western continental margin of North America, we cannot yet predict specific events of magnitude 7 or more with precisions better than about 100 years and 100 km. We do know, however, that the recurrence rate of events on the San Andreas fault has been on the order of 200 years over the last few thousand years, that geologically rapid displacements are still going on, and hence that California is obviously a high-risk region where we would not place a repository if we fear the hazards of earthquakes.

On the other hand, we cannot claim the probability of an earthquake is identically zero anywhere in the world because the origins of earthquakes in the interior of the continent (New Madrid, 1811) or at its passive margin (Charleston, 1886) remain pretty much a mystery. Had these events occurred a few generations earlier, before written records became available, we would not now be worried about destructive earthquakes in the central and eastern United States. About all that we can confidently say is that the earthquake risk is much less in some regions, say the Gulf Coastal Plain, than it is elsewhere, say along the trace of the San Andreas fault and its subsidiaries.

The hazards of earthquakes may well be overly exaggerated. Recent surveys by Professor H. Dowding of North-

western University and Dr. Howard R. Pratt of Terra Tek reveal that damage to underground openings is very much less than that to surface structures immediately above. Disruption would occur if a seismogenic fault actually transected an opening, but adequate site characterization should have eliminated this eventuality. Thus, once a repository has been sealed and its surface facilities abandoned, the effects even of large earthquakes are likely to be negligible.

It is well to recall that the earthquake history of the United States is based chiefly upon diaries or newspaper accounts, which may cover a time span varying from 300 years to a few decades, depending upon the area. The development of a widespread instrumented seismic network with sophisticated equipment and data processing is partly an outgrowth, during the past three decades, of the interest in detecting nuclear bomb blasts. Instrumental seismology has existed for decades, but systematic data compilation is relatively recent. On either basis, whether from an incomplete historical record stretching backward for up to three centuries, or from a compilation of seismic record data, perhaps adequate for only three decades, there is little reason for confidence in forward predictions covering a million years.

During the past three decades a series of qualitative seismic risk maps has been produced by the Coast and Geodetic Survey, the most recent of these in 1969. Responsibility for the next set of risk maps lies with the U.S. Geological Survey, but their own estimate is that a *reliable* seismic probability risk map lies a decade or more in the future. Even this assessment may be optimistic.

VII.2.3 *Glaciation, and Climatic Changes*

Geologic records of a glaciation in Alaska extend backwards for at least 10 million years and in the coterminous United States for more than 2 million years. De-

spite the generally adopted statement that there were only four major cycles of glaciation, it has now been demonstrated that there have been numerous glacial epochs, that they follow a cyclicity on the order of 10^5 years, and that they are predominantly controlled by the earth's orbital eccentricity, as proposed long ago by Milankovitch. Both theory and the now established record show that the bulk of these 10^5-year cycles represents glaciation for the Northern Hemisphere, with interglacial periods like the present one lasting on the order of 10,000-20,000 years. The current interglacial was established between 16,000 and 11,000 years ago. It is now predicted that the long-term trend for the next 20,000 years is toward extensive glaciation in the Northern Hemisphere. Although this forecast is in accord with climatic analyses that show a consistent cooling trend for the past three decades, the latter trend is too short to permit interpretation that the two are coupled.

The near certainty that re-glaciation will occur long before any disposal site will have fulfilled its assigned role implies that there will be other complications. The depth of bedrock scouring by ice sheets averages only 20 ft. However, re-routed streams have incised bedrock for depths of up to 200 ft; Niagara Falls, the best known example, has excavated a 170-ft-deep trench for a length of 7 mi during the past 10,000 years. Waxing icecaps cause isostatic depression of bedrock amounting to hundreds of feet, potentially producing faulting; waning icecaps allow isostatic rebound, more potential faulting and, with extreme melting, a good possibility for flooding continental margins to depths of 100 ft or more above present sea level.

Mean precipitation and evaporation differ markedly between glacial and interglacial times. We cannot assume that an area that is arid today will remain so during a glacial cycle. This is most obviously the case in Utah and Nevada where, during the recent glacial epochs,

there was a pronounced pluvial environment. What such a pluvial environment might do to the hydrologic regime in the site of an HLW repository seems to have been largely ignored in current risk assessments of repositories such as Hanford and the Nevada Test Site.

The Panel believes that continental re-glaciation has a very high probability of occurring within the time period of concern for HLW, and that the associated climatic changes will have differing effects on all waste repositories, depending on location. There may, however, be certain advantages to locating repositories in areas likely to be re-glaciated, because this would effectively seal them from intrusion several thousands of years hence.

A different problem arises from the potential combustion of coal and petroleum products. This, the so-called greenhouse effect, would be a warmer world-wide climate created by the CO_2 resulting from fuel burning. Even if the effect were not total melting of the Antarctic and Greenland ice-sheets, sea level would rise significantly. The evaluation of salt domes as repository sites should include consideration that such an eventuality is possible. If the top of the dome were accessible to seawater, extensive dissolution of the salt could occur, possibly exposing the HLW. Further, even if the greenhouse effect did not play a role, it is known that sea level has varied for different interglacial epochs and could be higher next time than it is now.

VII.3 FUTURE RESOURCE EXPLORATION

Although the energy supply appears to loom as the major mineral resource problem for the next few decades, this is only because its present urgency has diverted attention from far more important question of how the world's rapidly expanding population can maintain the raw material supplies necessary for an industrialized society. Current annual consumption of newly mined mineral products is 3.75 MT per person, and by 1985 this figure will

have doubled. Geochemical and economic arguments have been adduced to show that when the average ore grade of a metal slips below a critical level, the amount of energy needed to extract that mineral will far exceed any costs that society can reasonably pay for it, so the mineral will no longer be available. Mercury, silver, gold, copper, and lead are candidates for such early scarcity. The 1975 National Academy of Sciences Report of the Committee on Mineral Resources and the Environment has concluded that technology cannot always close the gap between rising demands and available resources, so we shall be inexorably driven to lower ore grades, larger tonnages, and other materials.

As an illustration of the enforced shift to increasing tonnages of decreasing grade we may cite uranium, for which the 1990 projected demand of U_3O_8 is 700,000 MT; production of this amount of U_3O_8 will be possible only if the present ore (economically mineable) grade (0.22% U_3O_8) falls to 0.075% in 1990.

From what is known of the world's mineral resource picture, it is difficult to be optimistic that industrialized society can sustain itself at anything approaching its current levels in the next millennium. A steady decline in the quality of life appears inevitable, as well as an increasingly desperate exploitation of raw materials. What the mineral exploitation might be like a thousand years from now is impossible to predict.

Of the rock types currently under consideration as hosts for HLW repositories, shale and basalt seem unlikely to assume an important economic role. Granite is somewhat different because there are some granites that potentially are mineable because they contain relatively large amounts of thorium, uranium, and rare earth. Several other types of ores are also associated with granites. The most likely targets for near-term exploitation, however, are salt domes because of the potential productivity of petroleum, halite, and sulfur; and bedded salt deposits

because of their potash, halite, and gypsum. The United States has only 4% of the world's total proven potash reserves, and most of these are concentrated in the New Mexico area now being evaluated as an HLW repository. Future conflicts between the demand for HLW repositories in bedded salt and the needs of agriculture for potash seem inevitable, and may even now constitute an important negative socio-economic factor in the development of some repositories. Such conflicts could be minimized in the case of salt domes by selection of domes that are barren of petroleum and sulfur.

VII.4 OTHER GEOLOGIC HAZARDS

Some data on rates of uplift and denudation may be used to underscore the unpredictable nature of so-called steady-state geologic processes. The average rate of regional denudation in the United States ($0.063\ m/10^3\ yr$) is such that it would require approximately 15 million years to uncover an HLW repository at the burial depths now planned. This seems to be such a large safety factor that we could easily relegate denudation to the status of a relatively minor risk. However, denudation rates vary by factors of up to 75, depending on climatic and topographic factors, so there is a large uncertainty in applying averages that are not site-specific.

Assuming that a repository is planned for a stable area of the continent, we may now ask how certain we are of this stability. The Adirondacks, long regarded as an ancient stable shield area, are now known to be rising at the rate of 3.7 mm/year in the center of the mountains. The beginning of the doming of the Adirondacks is not well dated, but at the present rate of uplift the 1,600 meters of maximum uplift, and subsequent deep erosion, could have taken place within a half-million years; but it could also, of course, have taken millions of years longer. Prior to the initiation of this recent uplift, there would have been no reason to predict that this

large area of the United States would be rapidly uplifted and eroded. There is also no basis for predicting where, or when, other such uplifts may occur on the stable shield of the continent. The point is that there is a finite but very low probability that a repository buried at a depth of 0.5 km almost anywhere might, within a relatively short time, unpredictably reappear at the earth's surface. How one can make an orders-of-magnitude conjecture concerning these probabilities is beyond the Panel's ability to resolve.

PART VIII: MONITORING THE REPOSITORY

Part of the responsible establishment of an HLW repository is the provision for a warning system in the event of loss of some of the HLW to the biosphere. If we assume that some form of monitoring for radioactivity will be mandatory, there are two aspects to this problem: early warning to permit some attempt to repair the site or confine the spread of the HLW, and longer range surveillance to provide warning in sufficient time to reduce exposure to the contamination. The first type of monitoring would be done close-in to detect early signs of the breach of the repository. For the second, more widely spaced monitors would be used.

Any close-in monitoring would, of necessity, include some connection with a surface-recording device, a means for replacement or repair of the sensor, and due consideration of the possibility that the sensing scheme itself could provide an additional pathway for migration of radionuclides. That monitoring be continued for a period of time on the order of at least several centuries for the fission products and one million years for the TRU wastes is a commitment that it is not reasonable to expect future inhabitants to fulfill.

There is no known instrumentation that has demonstrable reliability for decades, much less for centuries. Beyond those times, the radioactivity is much less, will have a

large alpha component, and the sensitivity of any currently available instrumentation to the losses would decrease markedly just when the sensitivity needed for detection would increase. The commitment must be to a repository that may be monitored remotely for some period of time, but we shall not know what is going on within the general confines of the repository once the monitors left in place malfunction.

Remote monitoring can be effected both from the surface and from the drill holes made to help define the site to begin with. However, such monitoring cannot define any activity such as migration that is occurring in the repository. A new technology would be needed to achieve this, and such a technology would first have to be shown to be possible.

An analysis of the nature of remote monitoring arrays pinpoints the very difficulty that predicting the direction and rate of migration of the HLW poses in the first place. Even if the overall hydrologic regime were well determined, small deviations from the average flow might still result in the arrival of some HLW at the surface. Such short-circuits could contain only a small fraction of the total HLW, but they could still have serious local effects. It is rarely possible to identify where such effects might occur, thus they are potentially hazardous even beyond the confines of the fenced-off reservation of a repository. We see no way to predict such occurrences either in time or space. It is not part of our charge to consider risk tradeoffs that might arise in the case of small numbers of people being at potentially serious risk in such cases. Consideration of this problem should be included in any monitoring scheme.

If our prediction of the behavior of a repository were quite accurate, we could allow for small losses that take sufficiently long times to arrive at a biosphere reservoir so as to be below presently specified maximum safe levels.

However, owing to the variable hydrologic regimes that would almost surely occur over the next million years, the leaks of the HLW might occur significantly earlier than predicted, but still much beyond any time when continuous monitoring can be anticipated. The TRU wastes that enter the biosphere undetected at such time in the far future might impose serious risks on our descendants.

PART IX: CONCLUSIONS

It should be emphasized that our intention is not to recommend what may be the best host rock or geographic location for HLW storage or disposal. Our intention is to identify gaps in the state of geological knowledge that may prohibit reasonable predictions to be made about events and processes that might occur in certain host lithologies. In some instances we feel compelled to indicate potential problems.

(1) Knowledge concerning the properties of the salt in dry domes is good. If the HLW canisters are not to be retrieved after the 5 or 10 years needed to complete the filling of the repository, then the short-time deformations in dry salt domes around the canisters can be computed and reasonable predictions are possible. Disposal would be permanent because at the expectable high temperatures, the high-density canisters would probably sink into the salt. The usual assumption seems to be that the salt is indeed dry. This is clearly not so in certain bedded deposits or in all domes. Careful measurements of water content will be most important. Further, even dry salt contains some water, so that the sinking of canisters computations, with the possibility of "focusing," should be done with this in mind.

(2) Retrievability of HLW in other rock types is not so much a question of locating the canisters because they have bodily moved elsewhere, but being able to collect all of the waste because corrosion and leaching might so disintegrate the canisters that much of it is dispersed. This problem is further exacerbated by the possibility of dispersal by fluids far away from the site. We believe that the appropriate computational methods for assessing such possibilities are known, but our knowledge of the access of the repository system to fluids via transport through cracks is not now adequate. Research is needed on how to determine the extent to which a repository is an "open" system. As a consequence, while several lithologies are potentially viable candidates for repositories that permit retrieval, not enough is known to permit a selection or priority assignment.

(3) There is a fundamental paradox to be encountered in the design and construction of a "closed" repository. It is desirable to avoid disturbance of the rock mass by exploration drilling as this provides extra pathways for the HLW to reach the surface. However, one must determine very precisely the geometric distribution of rock properties throughout the future repository site and its immediate surroundings. Prior to excavation, only careful examination of many drill cores can possibly delineate these properties. These two contradictory demands must somehow be resolved. Proper assessment may have to await excavation of shafts and adits, despite the high risk of the capital investment should the site then be found to be unsuitable.

(4) If the HLW is not reprocessed, U and Pu will pose long-term radiation hazards, as well as a

different chemistry of transport. It is unlikely, however, that the integrities of the canister, its contents, and its immediate surroundings will last very long, whether or not reprocessing is carried out. We have seen no evidence of survivals longer than a decade. The question of reprocessing does relate to the mix produced and thus the temperatures to be expected in the canisters as a result of the heat production from that mix.

(5) We are surprised and dismayed to discover how few relevant data are available on most of the candidate rock types even 30 years after wastes began to accumulate from weapons development. These rocks include granitic types, basalts, and shales. Furthermore, we are only just now learning about the problem of water in bedded salts, and the need for careful measurements of water content in domes.

(6) The state of knowledge concerning total permeability in jointed shales, granites, and basalts is still inadequate for meaningful forecasting. Total permeability includes all paths for fluid migration through the rock, including cracks, joints, faults, and inhomogeneities of lithology. The lack of such knowledge does not necessarily imply that a rock is unsuitable. Comparatively anhydrous rocks in the granitic clan or basalts might well be the best rock types for storage, and perhaps disposal, even though they are jointed and salt is not. Transport properties depend on both the chemical and mechanical nature of the rock.

(7) Two principal questions arise for all lithologic types other than the salt in domes:

1. How does one determine the real "permeability" of the rock mass surrounding the repository and extending to the surface, and
2. How does the permeability of the fissures affect solute-retardation factors relative to the flux of water throughout the rock mass?

Development of methods to answer the first question will be very hard, but must be undertaken. The plethora of distribution coefficient and retardation coefficient data now available provide a good start, but they are not adequate to address the critical problems of retardation under conditions of high ionic strength.

(8) Existing computational methods for assessing transport may well be adequate, and the accuracies of these models can be specified in principle. However, until the uncertainties of the input parameters are included in the numerical models, the reliability of any model remains undemonstrable. Further, while mathematical simulation of radioactive ion transport from the repository is an important and very useful tool in the risk analysis of an HLW repository, such simulations can be dangerously misleading unless careful attention is directed toward inherent physical and mathematical assumptions. Of particular concern here is the relatively superficial attempt to date to incorporate parameter uncertainty in the contaminant transport forecasts. It is of paramount importance that the analyst present unambiguous estimates of uncertainty in such forecasts so that decision-makers are not misled into believing that such forecasts are independent of parameter uncertainty.

(9) It seems clear that the uncertainties of forecasting the behaviors of conceptual HLW reposi-

tories are due principally to inadequate knowledge of the relevant mechanical, radiochemical, and hydrologic properties of the candidate rock types. Most of these can be measured by well established methods, but times required even for adequately funded research efforts are likely to vary widely—from a year or so to a decade or more.

As noted in the text, there are also several questions, notably the determination of real permeabilities and porosities in the rocks at a site, or the nature of the long-term monitoring systems, answers to which must await the invention of new technology. The time scale for such research is much less readily determined.

Except for the modest effort on salt, the geological aspect of the HLW repository problem had largely been neglected by our generation until a year or so ago. It will not be solved without a strong commitment of money and manpower, lasting beyond 1985.

[PORTIONS OF REPORT TO THE PRESIDENT BY THE INTERAGENCY REVIEW GROUP ON NUCLEAR WASTE MANAGEMENT, (TID-29442, March 1979) *]

REPORT TO THE PRESIDENT BY THE INTERAGENCY REVIEW GROUP ON NUCLEAR WASTE MANAGEMENT

March 1979

Washington, D.C.

[* The draft of this document was docketed in USNRC Rulemaking Docket No. RM-50-3 on May 25, 1978. *See* Certified Index of the Administrative Record in U.S. Court of Appeals Docket Nos. 79-2110 and 79-2131, Vol. 29, Doc. No. 13a, (reproduced *supra* p. 104). The final version (reprinted here in part) was relied on by the Commission in its Statement of Consideration on the Final Rule at footnote 24. *See* U.S. S.Ct. Docket No. 82-551, Pet. App. 367a n.24. The portions included from the Report are pages 37, 1.3 through 51, 1.25 and Appendix F (Risks Due to the Disposal of High-Level Radioactive Waste).]

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IRG Response:

The IRG has reviewed its judgments about when implementation might be able to begin for the various technology options and still feels that the statements in the draft IRG report are appropriate. The IRG agrees the technical options other than mined repositories might one day become the preferred approach for high level and transuranic waste disposal, but still considers the relative near-term emphasis to be placed on each should be as described within the interim strategic planning basis for high level waste.

The IRG believes that steady progress towards actual disposal of nuclear waste is the proper approach as opposed to long-term interim storage because of its belief that future generations should not be saddled with a growing inventory of existing wastes generated from activities from which they have received no benefit.

The IRG considers interim surface storage of spent fuel at reactors or at away-from-reactor storage facilities to be important components of its overall approach to waste management until a repository is available. Surface storage should not, however, be viewed as in any way an alternative to ultimate disposal. Technology for interim surface storage in water pools is currently well in hand and some R&D effort is directed at dry storage.

STATUS OF KNOWLEDGE ON MINED REPOSITORIES

Because of the need to isolate High-Level Wastes and TRU wastes from the biosphere for relatively long periods of time, and because disposal in mined repositories is the nearest term option, the IRG carefully reviewed the present status of scientific and technological knowledge pertinent to mined repositories. *The IRG review identified a number of important technical findings which it believes*

to represent the views of a majority of informed technical experts.

- *A systems approach should be used to select the geologic environment, repository site, and waste form.* A systems approach recognizes that, over thousands of years, the fate of radionuclides in a repository will be determined by the natural geologic environment, by the physical and chemical properties of the medium chosen for waste emplacement, by the waste form itself and other engineered barriers. If carefully selected, these factors can and should provide multiple, and to some extent independent, natural and engineered barriers to the release of radionuclides to the biosphere.

- *Overall scientific and technological knowledge is adequate to proceed with region selection and site characterization, despite the limitations in our current knowledge and modeling capability.* Successful isolation of radioactive wastes from the biosphere appears technically feasible for periods of thousands of years provided that the systems view is utilized rigorously to evaluate the suitability of sites and designs, to minimize the influence of future human activities and to select a waste form that is compatible with its host rock. Beyond a few thousand years and during the period of time in which actinides and long-lived fission products remain toxic, our capability to predict and therefore our assurance of successful isolation diminishes. Some uncertainties can be bounded or compensated for and, therefore, need not be resolved completely before selecting a site or constructing a repository. In addition, some will be resolved during repository construction. Although some residual uncertainty will always remain, reliance on conservative engineering practices and multiple

barriers can compensate for a lack of total knowledge and predictive capability.

- *Detailed studies of specific, potential repository sites in different geologic environments should begin immediately.* Generic studies of geologic media or risk assessment analyses of hypothetical sites, while useful for site selection, are not sufficient for some aspects of repository design or for site suitability determination. Detailed, time-consuming, site specific investigations are needed to determine the suitability of a particular site. The need to obtain access to specific potential repository sites is therefore urgent to assure the timely development of the first repository, and subsequently a series of repositories. Although most is known about the engineering aspects of a repository in salt, on purely technical grounds no particular geologic environment is an obvious preferred choice at this time. The system view implies that geologic environments and media heretofore not examined may be suitable for repository sites.

- *The actinide activity in TRU wastes and HLW suggest that both waste types present problems of comparable magnitude for the very long term (i.e., greater than a thousand years).* Although TRU does not generate a significant amount of heat, and has lower levels of penetrating radiation and transuranics per unit of weight than HLW, the transuranic content of a TRU waste repository could be significant. Therefore, the waste form and the leach rate, groundwater flow rate, and retardation factors used in selecting TRU waste repositories should be considered as carefully as when choosing HLW repository sites and design.

- *The degree of long-term isolation provided by a repository, viewed as a system, and the effects of*

changes in repository design, geology, climate, and human activities on the public health and safety can only be assessed through analytical modeling. Although work is needed to assure that all potential release mechanisms are considered, to improve modeling of groundwater flow through fractured media, and to evaluate or remove other uncertainties, bounding calculations can be performed in most instances so as to place reasonable limits on the expected behavior of a repository.

- *The effects of future human activity must be evaluated more carefully.* Relatively little attention has been devoted to the effects of future human activity on the repository or its hydrogeologic environment, or to the means available to the present generation for influencing such effects. Because it is not possible to predict or to restrict the activities of future generations, site selection guidelines, site suitability criteria, and repository design criteria must be developed in such a way as to minimize potentially deleterious effects of human activities.

Public Comment:

Numerous comments, of both a general and a specific nature, were received on the technical findings related to high level and transuranic waste disposal in mined repositories. Rather different and conflicting interpretations were made of some of these findings.

Those who believed the findings expressed a view that is too optimistic commented:

- The gaps in knowledge identified in Subgroup 1's Appendix A were not adequately reflected in the summary of the technical findings.
- The basis for attributing these findings to the majority of informed technical experts is not given. In fact technical opinion is divided.

- There is no more reason to have confidence in the IRG's findings than in similar previous statements by the National Academy of Sciences and other scientific bodies which over time have been shown to be inadequate.
- The findings were inconsistent with the more pessimistic reports of the GAO, EPA, USGS, and California Energy Commission.

Those who saw the findings as expressing a view that is too pessimistic observed:

- The findings are more pessimistic than warranted by the discussion in Subgroup 1's Appendix A.
- More acknowledgement should be given to the past accomplishments of the R&D programs that have been addressing high level waste disposal.
- The IRG should explicitly take a position that the problem can be solved. Some commenters noted that in their opinion this view has already been expressed by the National Academy of Sciences and the American Physical Society.

In general the systems approach, addressed in the first technical finding, was endorsed. Some commenters, however, questioned the meaning of the concept and criticized it for being contentless, full of jargon, and vague. Other individuals felt that more emphasis should have been placed on the need for multiple barriers to hedge against uncertainty while still others observed that the barriers might not be truly independent and therefore not provide sufficient protection. Another group of individuals said that more credit should be given to engineered barriers than the Draft Report does.

The second technical finding was widely regarded as the most important and was variously interpreted by different commenters to mean that the IRG concludes that:

- technology now exists to dispose safely of high level and transuranic wastes in mined repositories;

- insufficient information and expertise currently exist to be able to determine whether or not a site, once characterized, is suitable for a waste repository;
- much more work needs to be done before the technology is available to dispose safely of high level and transuranic waste

Most commenters agreed with their particular interpretation of the statement, although some disagreed with the statement as they interpreted it.

Some commenters interpreted the statement about salt in the third technical finding to mean that salt is an adequate host rock. Others argued that because most is known about the engineering aspects of a repository in salt, it is obviously preferred at this time. Others said that for a variety of reasons, most of which were identified in the Appendix A of the Subgroup 1 Draft Report, salt is not a suitable host rock. Several commenters stated that sites should not be investigated until EPA's general environmental criteria for repositories and/or NRC's standards are available.

Several commenters stated that the fourth technical finding does not take sufficient account of the difference in heat content and transuranic element content of TRU waste compared to high level waste, particularly if spent fuel rods are disposed of.

Several people commented that the modeling efforts mentioned in the fifth technical finding were not likely to be fruitful or valid and that bounding calculations could be quite inaccurate. Others said that the IRG seems overly willing to rely on the results of model calculations. Still others noted that modeling skills will improve in the future and therefore current deficiencies are not cause for delay.

The point was raised in connection with the sixth technical finding that more attention also needs to be given

to human and man caused changes in the environment, such as changes in rainfall patterns that could result from CO_2 buildup in the atmosphere.

Some commenters criticized the IRG for not having addressed the biological implications of radiation releases to the biosphere; and for not considering the possibility that our current understanding of this subject might underestimate the impacts.

IRG Response:

The basis for the technical findings was the Appendix A of the Draft Report of Subgroup 1 on Alternative Technology Strategies, TID-28818 (Draft). As stated in the Preface of that Appendix, several earlier drafts were widely distributed within the interested scientific and technical community. Hundreds of written and oral comments were received and were taken into account in producing the draft contained as Appendix A of the Draft Subgroup I Report. This effort is the basis for the IRG's statement that it believes its technical findings to represent the views of a majority of informed technical experts. This document will be further revised as necessary on the basis of comments received subsequent to its publication and will be republished in final form. The IRG, of course, recognizes that a wide range of view [*sic*] on some points exist within the scientific and technical community. It also concurs that the possibility of failure of sites to qualify for licensing, of course, exists, and that the public must be aware of such possibilities. The second technical finding, as revised and presented below, now addresses this possibility.

On setting forth its principal technical findings and conclusions concerning disposal in mined repositories, the IRG intended to describe the status of scientific and technical knowledge relevant to mined repositories and to draw only those technical conclusions which are warranted on the bases of that knowledge.

The IRG recognizes that the term "system approach" can be misunderstood. However, it believes that the use of this term in reference to mined repository, is now widely understood within the technical community and is quite useful. The IRG supports its continued use. The IRG also continues to endorse its statements contained in the first technical finding on the important subjects of multiple barriers and engineered barriers.

The IRG agrees that the second technical finding is particularly important and that as stated it can be interpreted to have quite different meaning. The IRG now wishes to restate the finding as follows:

Present scientific and technological knowledge is adequate to identify potential repository sites for further investigation. No scientific or technical reason is known that would prevent identifying a site that is suitable for a repository provided that the systems view is utilized rigorously to evaluate the suitability of sites and designs, and in minimizing the influence of future human activities. A suitable site is one at which a repository would meet predetermined criteria and which would provide a high degree of assurance that radioactive waste can be successfully isolated from a biosphere for periods of thousands of years. For periods beyond a few thousand years, our capability to assess the performance of the repository diminishes and the degree of assurance is therefore reduced. The feasibility of safely disposing of high level waste in mined repositories can only be assessed on the basis of specific investigations at and determinations of suitability of particular sites. Information obtained at each successive step of site selection and repository development will permit reevaluation of risks, uncertainties, and the ability of the site and repository to meet regulatory standards. Such re-evaluations would lead either to abandonment of the site or a decision to proceed to the next step. Reliance on conservative engineering practices and multiple independent barriers can reduce some risks

and compensate for some uncertainties. However, even at the time of decomissioning [*sic*] some uncertainty about repository performance will still exist. Thus, in addition to technical evaluation, a societal judgment that considers the level of risk and the associated uncertainty will be necessary.

While agreeing with the above revision of the second technical finding, some members of the IRG are still concerned that insufficient attention is given in this report to significant gaps and uncertainties in our current technical understanding. The scientific feasibility of the mined repository concept remains to be established. The preferred approach to long-term nuclear waste disposal may prove difficult to implement in practice and may involve residual risks for future generations which may be significant.

The IRG does not wish to endorse or criticize any particular potential host rock. Application of the systems approach to repository site selection and design implies that the suitability of any potential repository site depends on the geologic hydrologic, geochemical and engineering factors, including waste form, that comprise the total repository system. The properties of the host rock are important relevant factors but need not be the most important. Discussions of host rock suitability, independent of other factors, is therefore inappropriate and misleading.

The IRG recognizes the points raised concerning the differences in heat and transuranic element content. It still feels the statement made in the fourth technical finding is correct.

The IRG understands that model calculations, in this as in most other fields, have their intrinsic limitations. Nonetheless, if employed with sufficient care and adequate technical review, they have an important role to play in evaluating the risk of nuclear waste disposal in mined repositories. Indeed no other approach or risk assessment is available.

The IRG intended that the questions of human intrusion and man-induced changes in the environment (including the effects of CO buildup) be included within the term "future human activity" employed in the sixth technical finding.

The IRG recognizes that the biologic implications of radiation released to the biosphere and the possibility that new information might alter our understanding of those implications are important subjects. They have been and continue to be studied in the scientific community and are currently being addressed within the government by the Department of Health, Education and Welfare and by EPA and NRC as part of their regulatory activities. However, rather than duplicate these other efforts and in order to address the issue of greatest current controversy, the IRG chose to focus its attention on the mechanisms by which radioactivity might be released to the biosphere from a repository rather than what would be the biologic effects of such releases. Some members of the IRG in retrospect now believe the latter should have been done.

Risk Assessment

The risks associated with the long-term isolation of radioactive wastes cannot be verified or disproved on the basis of operating experience, experimentation or prototype testing. Rather, the risks to public health and environmental quality can only be assessed through mathematical modeling. Such a situation is not unique to the assessment of risks from many materials considered hazardous to human health and the environment such as arsenic, pesticides, carbon dioxide and fluorocarbons. The scientific community agrees that substantial further effort on risk assessment[2] of radioactive wastes in

[2] Risk assessment consists of failure-mode analysis, probability estimation, and consequence assessment. Failure-mode analysis, which is based largely on a combination of scientific reasoning,

geologic repositories, including site-specific assessments, is essential to determine the degree of long term isolation provided and the effects of changes in repository design, geology, climate, and human activities. The level of risk that the population might be subjected to can only be determined by assessments performed at repository sites. This is a result of the natural variability of rock mass properties and geologic heterogeneties [*sic*] which preclude the transfer of basic earth science information, or assessments performed with such information, from one site to another.

Once a repository is filled with radioactive waste and sealed, radionuclides contained in the waste can be returned to the biosphere in only two credible ways: (1) by exposure of the rock mass that contains the radionuclides, either through exhumation through physical movement of this mass to the surface; or (2) by dissolution of the waste by groundwater and movement of the radionuclides with the groundwater to a river, lake, well, or other point of discharge at the surface.

Either natural processes or human activities could conceivably lead to exposure of the buried waste, but current analyses indicate that, if appropriate site criteria are applied, the probability of exposure occurring would be quite small. Thus, the most likely mechanism of transfer is through dissolution and transport by groundwater. After a repository is breached by circulating groundwater, several barriers[8] should mitigate the consequences of the

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engineering, experience, and intuition, involves identifying events and sequences of events and processes that lead to the release of radioactive material into the biosphere. The probability of these events actually occurring is estimated, and the consequences, in terms of radiation doses or human health effects, of radioactive releases is quantified. Descriptions and results of a number of risk assessment studies are presented in Appendix F.

[8] Although the term barriers is frequently used in the literature, a more precise expression would be mechanisms that inhibit the dissolution of radionuclides and their transport to the biosphere.

breachment: the waste form that contains the radionuclides, if sufficiently inert, will inhibit the release of radionuclides into the water; the groundwater flow rate and flow path, if very slow and long, respectively, would allow the radionuclides to decay, perhaps to innocuous levels, by the time the water reached the biosphere and would allow sorption of radionuclides by rocks which would retard their movement.

One worst case assumption commonly made in risk assessment is that at some postulated time after the repository is closed the radionuclides in the waste will be completely dissolved in circulating groundwater or that they will dissolve at some specific rate. The time required for groundwater to reach the biosphere is estimated by assuming that the radionuclides move through surrounding formations along specified paths to the surface. The results of such an assumption are:

- radiation doses well above natural background levels, if the release occurs soon after closure of the repository or if flow paths to surface water are short, and
- radiation doses below natural background levels for long flow paths and for releases that occur in the very distant future.

Public Comment:

Some commenters disagreed with or felt uncomfortable with the statements that:

> "The risks associated with the long-term isolation of radioactive wastes cannot be verified or disproved on the basis of operating experience, experimentation, or prototype testing."

and

> "Some uncertainties can be bounded or compensated for and, therefore, need not be resolved completely."

A portion of these commenters argued that, taken together, these statements were a rationalization for moving ahead prematurely. In contrast, others felt that in fact more certainty could be obtained about the risk that the statements implied.

Several comments were received suggesting that the IRG's discussion of failure scenarios was inadequate. Some individuals maintained that

- there were plausible scenarios that would present greater hazards than the commonly used worst case scenarios identified in the Draft Report;
- the problem of glaciers was ignored; and
- the impact of climatic change, perhaps including an increase in sea level was ignored.

Finally, the IRG was criticized for not making any judgment on the social acceptability of the risks involved:

- either indirectly by comparison to risk associated with natural phenomena and/or other anthropogenic hazards;
- or directly by comparison to some standard such as the risks associated with naturally occurring ore bodies.

IRG Response:

The risk assessments performed to date, some of which are summarized in Appendix F to the IRG Draft Report and some others of which are cited in Section 4 of Appendix A of the Draft Report and Subgroup 1 have, with few exceptions, been based on idealized repository characteristics and are subject to significant uncertainties. These have been useful to advance the state of the methodology and to provide insight into the magnitude of risk to be expected from repositories whose features approximate the assumptions in the model. The IRG would like to emphasize, however, that risk assessment computations are needed which are site specific in the origin of their data and in their application and

only such assessments can truly apply to a specific site. Some uncertainties about the level of risk will always remain both because of the current state of the methodology of risk assessment and because of of its inherent limitations.

Uncertainties associated with risk assessment derive from lack of data, lack of experience, inability to identify all release mechanisms for radionuclides, the natural variability in physical properties of geologic media, and inability to predict long-term geologic and climatic processes and social evolution. All of these uncertainties are neither additive nor of equal significance. An important aspect of the research remaining to be done is to understand how each enters into the overall uncertainty of the calculation of risk.

Risk assessments can provide valuable information for assessing the generic feasibility of the technology, setting standards, and possibly, comparing alternative sites. The IRG believes that modeling and other risk analytical techniques should not be used uncritically and that, whenever practicable, tests and other experimental evidence should be employed. Care should particularly be taken to employ an adequate data base, properly qualify risk analysis results, identify uncertainties, and avoid misuse of the approach.

The IRG does not believe that it is its role to specify or imply what the appropriate social judgment of acceptable risk should be. Under current statutory authorities, this matter will be addressed through the EPA and NRC regulatory programs.

Technical Conservatism

Regardless of how minimal hypothesized adverse effects might be, *the IRG finds that the Federal government should maintain a technically conservative approach in pursuing the development of mined repositories for high-*

level and TRU waste disposal. For example, the repository could be loaded initially with coller [*sic*] waste or at a lower heat generation per acre than design studies suggest is necessary. The waste-emplacement rate could be lower during early operation to permit observation of a small number of waste filled canisters. And the repository could be designed, constructed, and operated so the emplacement waste could be retried [*sic*] during an initial period of operation.[4] The ability to retrieve emplaced waste acts as a hedge against unforeseen problems that could occur relatively soon after the wastes are emplaced and that might jeopardize the safe operation of the repository.

Because the necessary isolation periods for waste disposal are so long, no demonstration can prove the presumption of safety. Thus, a social consensus, based on scientific evidence, must be obtained through:

- Dissemination of fundamental scientific information
- The development, analysis, and near-term validation of long-term predictive models
- Extensive, independent, objective review of results by scientific experts, and of proposed facilities and operations through the licensing process
- Practical experience, including careful monitoring of the isolation systems
- A demonstrated capability to take any needed corrective or mitigating actions
- An ongoing R&D program to increase the state-of-the-art of knowledge

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[4] Retrievability here and elsewhere in this document means sealing each room and passageway after it is filled to close pathways to the environment, but keeping open the main shaft to permit removal of waste, if necessary, at a cost and level of difficulty not significantly greater than that incurred in emplacing the waste in the first place.

Only if such a social consensus is obtained can disposal of HLW and TRU waste in geologic formations actually be implemented and the public be confident that nuclear waste can be safely isolated in this way over very long periods of time.

Because mined repositories appear to offer a viable near-term opportunity for disposal of both HLW and TRU waste, the IRG used this technology as a central element for considering various interim strategic planning bases for disposal of these waste types.

Public Comment:

Most commenters on this subject endorsed the notion of technical conservatism. Some suggested it could and should obviate the necessity of intermediate scale facilities. Others suggested that an even more conservative approach would be to keep spent fuel in surface storage, perhaps for several decades, until it had greatly cooled or until a decision with respect to reprocessing is made. The comment was also made that the only results of proceeding in a conservative manner would be to delay the full operation of a repository and continue to undermine public confidence.

Many industry and some other commenters urged that if spent fuel is placed in a repository, retrievability should be maintained to keep open the option of reprocessing. Some commenters were concerned that the IRG presented no information about the circumstances in which removing the waste might be desirable, whether it would be possible in such adverse circumstances, or how long retrievability could be maintained under optimum conditions. The IRG was urged not to impose arbitrary limits on how much it was willing to spend to maintain retrievability and to recognize that retrievability is meaningful only if facilities are available into which the waste could be transferred if retrieved.

For a summary of comments made on the IRG's discussion of the need for "social consensus," please refer to the section on public participation.

IRG Response:

The IRG wishes to reiterate its view that a repository should begin operations in a technically conservative manner. By this is meant that margins of safety should be included in such design and construction features as heat loading, monitoring ability and rates of loading. There is a relationship between this concept and the notion of intermediate scale facilities which is addressed in the section on that topic.

The IRG agrees that there is a trade off between the advantages of rapidly isolating the waste from the environment and those associated with retrievability. Further analysis is required and will be performed but currently the compromise expressed in the footnote on page [*393*] seems reasonable from a technical perspective as an interim design basis.

The IRG's retrievability approach is directed at technical conservatism and safety considerations, not future reprocessing. The IRG does not agree that any other function of retrievability in a repository is appropriate. Further, the cost estimate in that footnote was not intended as a limit on how much should be spent to retrieve waste, but rather just an estimate of what the cost would be to remove the waste should that prove necessary and if the procedure suggested were followed. Further technical work will be necessary to assure retrievability for reasonable time periods in particular geologic settings. In some instances special containers and packaging may be required. Assessment is also necessary of the circumstances in which removal of the wastes would be desirable. The IRG agrees that for such removal to be possible, alternative facilities must be available. Surface facilities at the site will provide some capability and the

opening of repositories earlier than absolutely necessary in order to implement the regionality concept would also provide back-up.

The discussion of technical conservatism in this section is limited to the application of this concept to the design, engineering and heat loading aspects of mined repositories. A broader application of this concept is contained in the later section on the IRG recommendation on the near term approach to HLW disposal.

INTERIM STRATEGIC PLANNING BASIS FOR HLW DISPOSAL

The choice of technical strategies for the disposal of HLW and its implementation must await completion of the appropriate Generic Environmental Impact Statement (GEIS) required by NEPA. However, because near-term waste management programs must be developed, priorities assigned and R&D activities planned prior to the completion of the NEPA process and selection of a strategy, a clear interim strategic planning basis must be set forth. It must be designed and executed in a way that does not prejudice the NEPA process. In particular, interim decisions must be of a nature that preserves options rather than forecloses them. It is unacceptable to conduct a NEPA review, the outcome of which has been largely predetermined or one that is carried out mainly to justify or ratify decisions already made.

This section is basically a reiteration of views previously presented in Chapter I of the Draft Report under the heading "Development of An Interim Strategic Planning Basis." Public comment and IRG response related to this matter are accordingly located at that earlier point in the document.

INITIAL DEFINITION OF TECHNICAL STRATEGIES

The IRG established a special subgroup to provide it with analysis of potential technical strategies for the disposal

of HLW.[5] As an input to the IRG deliberations, the IRG Staff Subgroup on Alternative Technologies defined and evaluated four technical strategies for HLW disposal:

- Strategy I provides that only mined repositories would be considered and that only geological environments with salt as the emplacement media would be considered for the first several repositories. As a result of past focusing on salt, there is a large volume of information available. In addition, one body of opinion holds that salt is the best, or at least an acceptable, emplacement medium and that suitable sites can be found where salt is the host rock.

- Strategy II provides that, for the first few facilities, only mined repositories would be considered. A choice of site for the first repository would be made from among whatever types of environments have been adequately characterized at the time of choice. Because generic understanding of engineering features of a salt repository are most advanced, the first choice is expected to be made from environments based on salt geology. Sites from a wider range of geologic environments would be available for selection somewhat later.

- Strategy III provides that, for the first facility only mined repositories would be considered. However, three to five geological environments possessing a wide variety of emplacement media would be examined before a selection was made. Other technological options would be contenders as soon as they had been shown to be technologically sound and economically feasible.

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[5] Details of this analysis are reported in draft in "Alternative Technology Strategies for the Isolation of Nuclear Wastes," prepared by Subgroup One of the IRG, October 19, 1978.

- Strategy IV provides that the choice of technical options and, if appropriate, geological environment be made only after information about a number of environments and other technical options has been obtained.

These strategies were defined by the IRG Subgroup so as to illustrate particular characteristics of a range of possible strategic approaches. These were not intended to be a complete list of possible strategies or comprehensive descriptions of a strategic planning basis that might actually be adopted by the waste disposal program. For the latter purpose, they are admittedly incomplete.

Two other significant matters must be included with any such complete description. These two additional considererations, which are discussed below, are (1) regional site selection and (2) the use of intermediate scale facilities.

Public Comment:

Some commenters argued that the ocean sediment disposal option should have received greater prominence in each of the four illustrative strategies of this section.

The statement of Strategy I would be more balanced, one commenter said, if the following sentence were added: "Others are of the opinion that salt is not an acceptable emplacement medium for a high level waste repository."

Some commenters were confused by the introduction of Strategies I through IV. Others by the absence of a discussion of their relationship to the proposed interim strategic planning basis for high level waste discussed later in this report, including the open question of whether to plan to select the first repository site from a limited or a broader choice of geologic environments.

Some commenters raised the question about what would constitute reasonable alternatives for examination

to fulfill the requirements of NEPA. Adoption of the systems view, they indicated, implies that comparisons must be made of alternative sites. An approach which first narrows to a particular emplacement medium and then only considers sites where that medium would be the host rock is not consistent with a system view.

IRG Response:

The IRG views on ocean disposal presented in the draft Report were not dependent on the treatment of this subject in the initial alternative strategies.

The IRG accepts the suggested addition to the statement of Strategy I. The IRG wishes to reiterate that Strategies I through IV were defined by Subgroup I only to illustrate particular characteristics of a range of possible strategic approaches and have no further significance. The IRG's proposed interim strategic planning basis is consistent with Strategy III in its treatment of non-repository technology options and its expansion of the breadth of the R&D and site characterization programs. It added the notion of regional siting and included a role for intermediate scale facilities. The first option of the open issue would be consistent with Strategy II's approach to siting the first repository and the second option would be consistent with Strategy III's approach.

The IRG agrees that the systems view is site specific and recognizes the interaction between geologic environment, media, waste form and other barriers and engineering aspects of repository design. These are seen most clearly when specific sites and specific repository designs are viewed as an integrated system. The IRG agrees that within an overall program which is looking at several potential media and a variety of geologic environments, it is consistent with the systems view to use the potential host rock as an organizing principle to lo-

cate alternative sites. Other organizational approaches (e.g., geographic, hydrogeologic, geochemical, etc.) are also possible and some may prove, on balance, to be better than others. Each organizing principle has certain benefits and certain liabilities.

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APPENDIX F

Risks Due to the Disposal of High Level Radioactive Waste

I. *Introduction*

This appendix discusses the problem of isolating high level radioactive wastes from the biosphere, the risk due to the wastes, and the current status of risk assessments. Extended discussion may be found in Appendix A of the Subgroup One report on Alternative Technology Strategies.

Basic Principles and Concepts

The intense radioactivity and persistence over several hundreds to hundreds of thousands of years of radionuclides contained in high level wastes make it imperative that these be isolated from the biosphere until they have decayed to safe levels of activity. Emplacement in a conventionally mined geologic repository is the most readily implemented means of effecting such isolation. Once such a repository is filled with radioactive waste and sealed, radionuclides contained in the waste can be returned to the biosphere in only two credible ways: (1) by exposure of the rock mass that contains the radionuclides, either through exhumation or through physical movement of this mass to the surface; or (2) by dissolution of the waste by ground water and movement of the radionuclides with the ground water to a river, lake, well, or other point of discharge at the surface. Either natural processes or human activities could conceivably lead to exposure of the buried waste, but analysis indicates that if appropriate site criteria are applied, the probability of this occuring would be negligible. Thus, the most likely mechanism of transfer is through dissolution and transport by ground water.

The task of accurately predicting over periods of several hundreds to hundreds of thousands of years the fate of deeply buried radionuclides is, to say the least, unprecedented and challenging. The problem involves three im-

portant aspects: first, the amount and rate of supply of radionuclides to the ground water; second, the pathways and rate of groundwater movement; and third, the degree of retardation of radionuclide movement caused by chemical interactions with the porous media through which the ground water moves. All three aspects influence, and any one of the three conceivably could independently control, the potential hazard imposed by radionuclide migration from a geologic repository.

The risks associated with the disposal and long-term isolation of radioactive wastes cannot be verified or disproved on the basis of operating experience, experimentation, or prototype testing (mathematical modeling). Rather, the risks to public health and the quality of the environment must be assessed through a complicated chain of inference and hypothesis. Such a situation is not unique to the assessment of risks due to radioactive wastes, but is common to the assessment of risk due to many materials hazardous to human health and the environment (e.g., arsenic, pesticides, carbon dioxide, fluorocarbons, etc.).

The assessment of risk basically consists of three types of activities—failure mode analysis, probability estimation, and consequence assessment. Failure mode analysis involves the identification of potential release initiating events and sequences of events and processes (scenarios) that lead to the release of radioactive material to the biosphere. Failure mode analysis is based largely on a combination of scientific reasoning, engineering experience, and intuition; there is no method to assure that such analysis identifies all potential events of significance. However, with time it is possible to increase our confidence that the dominant contributors to risk have been identified. The second step in risk assessment involves an estimation of probabilities associated with the scenarios identified in the failure mode analysis. This final step in risk assessment is the determination of the consequences of the potential releases of radioactive

materials as identified in the failure mode analysis. The consequences are typically quantified in terms of radiation doses or human health effects.

Approaches to Management of Wastes

There are two basic approaches to management of any waste: dilute and disperse, or capture and isolate. Historically, the dispersion approach has been used for many wastes (including some radioactive wastes or effluents) with the expectation that dilution and natural phenomena would be sufficient to maintain public health and environmental risks at acceptable levels. It has long been recognized, however, that dispersion would not be an acceptable approach to management of most radioactive wastes from defense related programs and commerical nuclear power. Management of these wastes is therefore based on isolation. If the wastes can be successfully isolated for time periods sufficient for the radioactivity to decay to low levels, risks can be avoided or maintained at negligible levels.

Principles of Waste Isolation

To help assure effective isolation of radioactive wastes from the biosphere, reliance is placed on the multiple barrier concept. In this concept, the principal barrier is a sufficiently long "travel time" for radionuclides to be transported by ground water. Additional barriers are provided by engineered features such as the waste form itself, the canister and overpacking material, and natural features which contribute to chemical retardation of radionuclides that might be dissolved in the ground water. Not all barriers are mutually independent. Clearly, for the multiple barrier concept to be valid, each barrier must either stand independently or its effectiveness must be evaluated in consideration of possible changes in other barriers.

In addition to reliance on multiple barriers for isolation of radioactive waste, the repository itself will be sited and designed to minimize both the likelihood of disruptive events affecting it and the consequences of such disruptive

events. The proper siting of the repository is achieved by utilizing adequate site selection criteria. The repository can be designed to minimize the effects of the repository on its geologic and hydrogeologic environment.

II. *Risk Estimation Methods*

As previously noted, risk estimation requires three separate activities. These are briefly addressed below.

Failure Mode Analysis

It is expected that only areas with a history of geologic stability will be considered as potential candidates for waste repositories. Past stability would appear to be a reasonable requirement for repository site selection. However, a history of geologic stability is not sufficient to assure future stability for the area, with or without the development of a repository. The development of a waste repository could contribute to a significant alteration of the local stress field, and no amount of backfilling or sealing of shafts will restore the area completely to its original conditions. Once a repository is filled and sealed, the area containing it might evolve differently than if the repository had not been placed there. Potential failure modes therefore are of two types, those that are self induced and those that occur independently of the presence of the repository.

Failure mode analysis attempts to identify mechanisms by which radionuclides could leave a repository, travel through surrounding formations, and enter the biosphere. The most important aspect of failure mode analysis is the development of plausible scenarios by which the repository system, with its multiple barriers, allows the release and transport of radionuclides from stored wastes. The end result is a time dependent estimate of the quantity of radionuclides reaching the biosphere.

Much of the risk assessment work to date has dealt with failure mode analysis. In general, potentially adverse in-

fluences on repository stability are grouped into sets associated with:

- Sudden disruptive events and processes (e.g., meteorite impact, earthquakes, vulcanism).
- Slow disruptive events and processes (e.g., dissolution by ground water, rock deformation, regional uplift and erosion, glaciation).
- Engineering related problems (e.g., shaft seal failures, thermal stresses, chemical effects).
- Human-caused events independent of the repository (e.g., inadvertent drilling, dams, surface explosions).
- Undetected features (e.g., shear zones, mineral resources, boreholes and cavities).

Although the identification of dominant mechanisms of release should be a primary goal, the results of published risk assessments are inconsistent in this regard. This inconsistency largely reflects our lack of detailed knowledge of the system and how it might behave in the future. More detailed risk assessments, now in progress, might lead to consistency in identifying dominant mechanisms, and possibly to event sequences that contribute most substantially to those mechanisms.

Probability Estimation

An important limitation in the ability to assess risk lies in assigning probabilities to geological processes and events both for the long term and for immediate engineering interest. Development of probabilistic models in the earth sciences is recent, but advancement of the techniques is proceeding rapidly. The difficulties of modeling geologic and hydrologic processes is a serious limitation to risk assessment. It is possible that "conditional" risks might have to be calculated—i.e., risks that would exist if the assumptions made in the analysis about future events

(climatic factors, land use, etc.) hold. This approach has precedent in other areas of nuclear safety and policy analysis for public risk.

Consequence Assessment

If radionuclides are released from the point of emplacement of waste, they must move through surrounding geologic strata before entering the biosphere. This movement will be substantially controlled by the hydrogeologic regime, inasmuch as ground water provides the means for movement of dissolved radionuclides. The flow field and potential pathways for dissolved waste to reach the biosphere are difficult to predict for times in the future, but appropriate bounds can be placed on them.

One assumption commonly made in risk assessments is that at some postulated time after closure of the repository, the radionuclides in the waste are completely dissolved in circulating ground water or that they dissolve at a specific rate. The time required for their movement to the environment is then estimated by assuming that the radionuclides move through surrounding formations along specified paths to the surface. The pathways can be arbitrarily defined, or determined by sophisticated groundwater transport modeling.

Radionuclides dissolved in circulating groundwater can enter the biosphere in a variety of ways, such as discharge of ground water to surface water (e.g., springs, rivers, etc.), and withdrawal of contaminated well water by humans.

Analysis of environmental impact and human uptake of radionuclides can add as much, possibly even more, uncertainty to the evaluation of risk as that associated with release of wastes from the repository and their movement through the subsurface. Surface features, particularly those that might be influenced by humans, such as river flow rates, creation of lakes and dams, and changes in

water runoff patterns, can be expected to change more rapidly than subsurface features, and might be less predictable.

Factors directly related to future human actions play a prominent role in determining the effects on humans of released radioactive wastes. One of the more important uncertainties is population density in areas that could potentially become contaminated. Population density could vary from zero to far higher than that now in the most densely populated cities. Furthermore, factors related to water usage are important. For example, irrigation from contaminated river or ground water would significantly increase the contamination of food crops and thus increase the human uptake of radionuclides through food chains. Nevertheless, as with certain geologic and climatic factors, bounds can be placed on the ranges of demographic and other human factors, or comparative consequences assessments can be made by adopting consistent assumptions within which each alternative will be (conditionally) judged.

III. *Existing Waste Isolation Safety Evaluations*

Nine available studies of waste isolation safety were briefly reviewed while preparing this report. No two of the nine studies reviewed were found to be directly comparable; a variety of analytical models, assumptions, geologic settings, numerical values for physical parameters were used. Only five of the studies addressed the water intrusion scenario, but scenario conditions, assumptions, and results differed as summarized in Table F-1.

Results of the studies are reported in various ways, including increments to radioactivity concentration in the environment, radiation doses to humans, and health effects resulting from radiation doses. Development of a common metric, if possible, is expected to require extensive analysis and cross-comparison. Some of the studies

are risk estimates (probabilities and consequences are estimated) and some are consequence estimates only, i.e., the time and circumstances of release from isolation are assumed. Collectively, the studies illustrate the range of methods, assumptions, and results that are possible.

Qualitatively, the studies reviewed can be said to be of three types: optimistic, best-estimate, and worst-case. It is often difficult, however, to classify a given study as it might contain assumptions of all three types. The comparative evaluation suggests, however, the following generalized characterizations of results in the three categories:

- Worst-case studies have predicted adverse effects that can be manifested as measurable increments to radioactivity concentrations in the environment or to radiation dose. Some of the assumptions involved in these studies can be classified as highly conservative.
- Studies classified as best-estimate appear to predict adverse effects that are factors of about ten thousand to one million lower than those for the worst case studies.
- The one study classified as optimistic predicts effects that are vanishingly small. It did not, however, consider phenomena that are acknowledged to be potential causes of radionuclide release from a repository.

Summaries of Studies Reviewed

This section identifies and briefly summarizes the nine studies reviewed. In most cases, results were presented in extensive tables that cannot be readily summarized or reproduced here. Results are therefore expressed as order-of-magnitude estimates derived from the actual information provided by the authors. The interested reader is referred to the original document for details.

1. H.C. Claiborne and F.,Gera, *Potential Containment Failure Mechanisms and Their Consequences at a Radioactive Waste Repository in Bedded Salt in New Mexico*, ORNL-TM-4639, Oak Ridge National Laboratory, Oak Ridge, TN (1974).

This study examined potential containment failure mechanisms and, in some cases, estimated their probabilities and consequences. Two classes of containment failure were considered—anthropogenic and natural. Anthropogenic failure mechanisms include: 1) sabotage, 2) nuclear warfare, and 3) drilling. Sabotage was dismissed as being extremely difficult to effect a release of radioactive wastes from the repository. Nuclear warfare as a means of excavating the waste was dismissed because of the extremely high nuclear yield which would be required. The consequences of drilling into the repository were felt to be minor.

Natural causes of containment failure include meteorite impact, volcanism, faulting, and erosion. Consequences are calculated for meteorite impact and faulting through the repository.

Consequence calculations for meteorite impact and faulting through the repository appear conservative. It is difficult, however, to assess whether the results are conservative (moderate) or optimistic from a risk point of view. Releases resulting from processes and events initiated by the presence of the repository are not considered. These releases could result from shaft seal failure, cracking caused by thermal expansion or subsidence, or other processes. The probability of release by self-induced mechanisms may be higher than the failure probabilities considered in this report.

2. H. C. Burkholder, M. O. Cloninger, D. A. Baker, and G. Jansen, "Incentives for Partitioning High-Level Waste," *Nuclear Technology*, 31, 202 (1976).

The authors estimated the dose consequences of groundwater transport of radionuclides from a high-level waste

repository. The discharge of radio nuclides was assumed to be into a major river. The waste form, the repository, and the surrounding geologic, hydrogeologic, and geochemical environment were analyzed, and the doses were calculated for individuals living within the region of influence of the site at various times after disposal. By varying the values of important parameters, the sensitivity of the dose consequences to the degree of effectiveness of multiple barriers was estimated. The results showed that for "reasonable" isolation conditions the potential maximum incremental radiation doses were of the same order as or less than doses from natural sources.

The parametric variations showed that the dose results were strongly sensitive to the effectiveness of the chemical retardation of radionuclide transport, moderately sensitive to the leach rate of and weakly sensitive to the time when initial contact of groundwater and the wastes occurs particularly after the first 1000 years) [*sic*].

3. H. C. Burkholder, "Management Perspectives for Nuclear Fuel Cycle Wastes," *Nuclear Waste Management and Transportation Quarterly Progress Report* January through March 1976, BNWL-2029, Battelle Pacific Northwest Laboratory, Richland, WA (1976).

This study extended the consequence estimations done for high-level wastes by Burkholder et al to other nuclear fuel cycle wastes. The projected maximum incremental doses were of the order of 50 times background or less for spent fuel disposal.

The potential doses from the spent fuel were larger than those from the solidified high-level reprocessing waste because of the increased amounts of uranium and plutonium in the spent fuel which ultimately decayed to the dominant dose contributor, 226 Ra.

4. B. L. Cohen, "High-Level Radioactive Waste from Light Water Reactors," *Reviews of Modern Physics*, 49, 1 (1977).

This paper is a comprehensive tutorial on the generation, disposal, and time-dependent properties of high-level waste. The estimates of risk are based on a comparison between an atom of waste buried at a depth of 600 m and a typical atom of radium in the rock and soil above the waste canister. The key assumption is that the waste atom is no more likely to escape and find its way to a human than the radium atom. Cohen argues that the assumption is conservative because the material above the waste canister includes near-surface soils where erosion is active. Others would argue that the assumption should be considered quite optimistic because radium is scattered fairly uniformly and is an intrinsic part of the soil and rock, whereas the radioactive waste is high [*sic*] concentrated and located in an area perturbed by excavation of the repository and by the heat from the waste itself. Escape of wastes from the repository would most likely result from those events and processes initiated by the presence of the repository and the radioactive waste.

Cohen further argues that natural delays such as the time required for circulating ground water to contact the waste and the travel time for dissolved waste to reach a discharge location assure that the waste would not reach the environment for the first few hundred years. However, results are presented for releases assumed to occur in the first few hundred years. The calculations predict a new probability that waste from the repository will be ingested by people of 4x10-13 [*sic*] per year. Results were extended to a prediction of less that [*sic*] 0.4 waste-caused cancer deaths during the first million years after disposal. The risk results might be increased significantly by other assumptions, e.g., withdrawal of contaminated ground water form [*sic*] a well in the vicinity of the repository.

5. G. deMarsily, E. Ledouns, A. Barbreau, and J. Margat, "Nuclear Waste Disposal: Can the Geologist Guarantee Isolation?" *Scienc* 197 [*sic*] 519 (1977).

This study examined the migration of radionuclides from solidified high-level reprocessing wastes in geologic formations. The repository depth was 500 m with water assumed to be present and moving upward. Five geologic media with properties ranging from highly effective to poorly effective in chemical retardation of radionuclides to transport are considered. Results of the study are expressed as concentrations of radionuclides in ground water discharging at the earth's surface. The other major parameter varied in the study is the leach rate of the waste.

The study combines highly conservative, moderate and highly optimistic assumptions in a way which make classification of the results very difficult. The results probably span the range from conservative to optimistic. Calculations are only performed for I-129, Np-237, and Pu-239 even though, under some assumptions, the transfer time to the earth's surface is only a few years. Other actinides, Tc 99, and some shorter-lived fission products should possibly be included to get more comprehensive results.

6. F. Girardi, G. Bertozzi, and M. D'Alessandro, "Long-Term Risk Assessment of Radioactive Waste Disposal in Geological Formations," EUR 5902.e, Commission of the European Communities, Ispra, Italy (1977).

This study performed a fault tree analysis of the potential scenarios for release from geologic isolation. It concluded that exhumation of the waste by humans was the most likely scenario for the first 100,000 years and ground water intrusion and dissolved waste transport were estimated but no chemical retardation of radionu-

clides was assumed. The maximum projected doses were in the order of 2-5% of natural radiation sources, for high-level wastes. TRU wastes were also included in the study and were found to cause slightly high doses. Results for high-level waste are summarized in Table F-1.

7. M. D. Hill and P. D. Grimwood, "Preliminary Assessment of the Radiological Protection Aspects of Disposal of High-Level Waste in Geologic Formations," NRPB-R69 National Radiological Protection Board, Harwell, U.K. (1978).

This study estimated the dose consequences for the groundwater intrusion scenario for the same set of conditions as those of Burkholder et al. The assumed initial waste inventory was about 10 times smaller, however, and different modeling techniques were used for both transport in the geologic environment and the biosphere. The maximum projected doses were on the order of 2 to 5% of natural radiation sources.

Sensitivity calculations were performed for five of the geologic environment transport parameters. These calculations showed that both the nuclide transport and leach resistances were important controllers of the projected doses for the situations investigated. Results are summarized in Table F-1.

8. Nuclear Fuel Safety Group, "Handling of Spent Nuclear Fuel and Final Storage of Vitrified High-Level Reprocessing Waste," Karn - Bransle - Sakerhet Stockhol [*sic*], Sweden (1978).

The Swedish Nuclear Fuel Safety Group estimated the dose consequences of groundwater intrusion into the radionuclide transport from high-level waste repository in Swedish granite. Three types of discharge to the biosphere was assumed: 1) lake, 2) underground well, and 3) Baltic Sea. The assumptions made for the calculations were thought to conservatively represent Swedish

conditions. Transport of radioactivity through the geologic environment was modeled using a variant of the computer code applied by Burkholder et al; projected doses were greatest in the well case with values on the order of one-tenth of natural radiation sources. Results are summarized in Table F-1.

9. S. E. Logan and M. C. Berban, *Development and Application of a Risk Assessment Method for Radioactive Waste Management*, EPA 520/6-78-005 U.S. Environmental Protection Agency Office of Radiation Programs; Washington, DC (1978).

The study devoted significant effort to determining radiation dose rates. From a consequence standpoint the results would appear to be conservative. However, from a risk point of view, it is difficult to determine whether the study is conservative or optimistic. For example, the scenarios considered are incomplete. Scenarios such as release to ground water via mine shaft or repository shaft leaks, or deliberate or accidental penetration of repository by drilling are not considered.

The use of fault tree analysis to represent the various geologic events makes it necessary to use estimated event probabilities and estimated release fractions which are not, in general, justifiably accurate.

Interpretation of Available Results

One possible conclusion that can be drawn from available studies is that none precludes reasonable assurance of obtaining an adequate level of safety. In fact, they suggest that the risks will be quite small. For the worst cases envisaged and studied to date, hazards would be discernable but small. A close examination of the boundary conditions utilized in the six studies that considered groundwater transport can however lead to the opposite conclusion. For example the two Burkholder studies (Table F-1), and the Hill and Grimwood study which

TABLE F-1

SUMMARY OF WATER INTRUSION SCENARIO SYSTEMS

REFERENCE	SCENARIO	TIME OF INITIAL RELEASE AFTER CLOSURE (yr)	LEACH TIME (yr)	GROUND WATER TRAVEL TIME TO BIOSPHERE (yr)	RETARDATION FACTOR ($^{V}water/^{V}sat$)	REPOSITORY INCLUDE INVENTORY (Ci)	CRITICAL RADIONUCLIDE	50-Yr ACCUMULATED DOSE TO INDIVIDUAL (mrem)	CRITICAL ORGAN	TIME AFTER CLOSURE THAT DOSE IS RECEIVED (yr)
Burkholder et al	High-level; Leach Incident; Discharge to river	100	20,000	150	1 10 100 500	2.88×10^{0} 1.03×10^{1} 6.07×10^{1} 0.347	^{99}Tc ^{14}C ^{237}Np ^{238}Pu	500 3,000 150 2,400	GI-LLI Bone Bone Bone	250 1,700 15,000 2,100,000
Burkholder et al	Spent Fuel; Leach Incident; Discharge to river	None as Above	2,000	None as Above	None as Above	None as Above	None as Above	2,000 20,000 1,200 200,000	None as Above	None as Above
Swedish Safety Study	High-level; Leach Incident; Discharge to well	1000	20,000	400	1 700 43 200	140×10^{3} 20 750 6400	^{99}Tc ^{226}Ra ^{234}U ^{237}Np	150 130 130 450	GI LLI Bone Bone Bone	13,000 80,000 80,000 130,000
Girardi et al	High level; Leach Incident; Discharge to river	1000	17,000	0	-0-	5.3×10^{0} 5.3×10^{1}	^{241}Am ^{243}Am	100 200	None Lung	1,000
Hill and Grimmond	High-Level; Leach Incident; Discharge to river	1000	5,000	100	1 100 500	1.0×10^{0} 1.0×10^{1} ?	^{99}Tc ^{237}Np ^{238}Pu	25 DF41 25 DF41 25 DF41	GI-LLI Bone Bone	100 ? ?

used the same conditions as did Burkholder, assumes that the ground water from the repository discharges into a major river (10,000 cubic feet per second flow) with an attendent several orders of magnitude dilution of radionuclide content. The discharge cited is comparable to the mean annual discharge rate of the Delaware River at Trenton, N.J., and indeed, if such a boundary condition persists over the time frames cited in Table F-1 (up to 2,100,000 years) then a highly effective mechanism for waste dilution exists. However, over time frames of even tens of thousands of years, and as a result of erosion or tectonics, several plausible conditions unfavorable to radionuclide dilution and perhaps even favorable to nuclide concentration could occur. For example, a large marsh might exist at the location of the present river with the attendant possibility of radionuclide concentration by aquatic food chains. Similarly the flow of the river could decrease significantly over such time frames, or the groundwater flow be diverted away from the river. Additionally, the Burkholder studies do not consider the possibility of human use of, and radionuclide concentration in ground water between the repository and the major river.

The model studies summarized unquestionably are useful in that they provide an appreciation for the interrelationship and importance of the numerous hydrogeologic, geochemical, rock mechanic and engineering parameters affecting the behavior of radionuclides placed in a repository. Conclusions drawn from such studies are valuable to the degree that the boundary conditions used and the uncertainties of data input and output are clearly stated. Whether or not conditions at a potential repository site match favorable hypothetical scenarios modeled must of course await detailed site specific studies.